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BOLL WEEVIL

Anthonomus grandis Boheman

Abstracts of Research Publications 1966-80

Compiled by C. R. Parencia, Jr. (collaborator), W. P. Scott, and J. W. Smith, Southern Field Crop Insect Management Laboratory, Delta States Research Center, Agricultural Research Service, Southern Region, Stoneville, Miss.

INTRODUCTION

U.S. Department of Agriculture Miscellaneous Publications 985 and 1092 gave abstracts of research publications from 1845 through 1960 and 1961 through 1965. Our compilation is a continuation of that work and covers literature published in the years 1966 through 1980. This publication has been prepared to serve as a guide to original publications for interested researchers.

The following sources were consulted: Biological Abstracts, S.D.C.'s International Search Service on BIOSIS PREVIEWS, Lucille and Norman Mitlin title compilations under contract with the U.S. Department of Agriculture, Agricultural Research Service, State agricultural experiment station publications, U.S. Department of Agriculture publications, professional journals, and Reports and Review of Applied Entomology.

For accuracy, the language of the author of the abstracted publication has been preserved wherever possible. Abstracts were prepared for some of the publications. Author and subject indexes are included.

We wish to express appreciation to the many authors who submitted copies of their articles, saving much in our time and reducing our requests for copies from our various library sources. The authors' expressions of encouragement were also appreciated and were instrumental in our keeping to the task at hand. We are indebted to Telecia Burton for so patiently typing the various drafts of the manuscript.

BIBLIOGRAPHY[1]

A

1. Ables, J. R.; House, V. S.; Jones, S. L.; and Bull, D. L. 1980. Effectiveness of diflubenzuron on boll weevils in central Texas River Bottoms area. Southwest. Entomol. Suppl. 1: 15-21.

In tests during 3 consecutive years, applications of the insect growth regulator (IGR) diflubenzuron caused substantial reductions in adult boll weevil emergence from field-collected infested squares. Generally, maximum reductions were produced 3-6 wk after initiation of treatments after which an apparent influx of untreated weevils reduced the effects of the IGR. Furthermore, results in 1976 demonstrated a distinct difference in weevil responses to different doses of the IGR. In that year, season averages of boll weevil mortality were 46.4, 67.4, and 77.3% at the 35, 70, and 140 g a.i./ha rates, respectively. We conclude that optimum use of diflubenzuron in the central Texas River Bottoms and other areas may involve other strategies such as area-wide treatments, planting of rapidly fruiting determinant cotton varieties, and fall diapause control programs.

2. ; Jones, S. L.; and Bee, M. J. 1977. Effect of diflubenzuron on beneficial arthropods associated with cotton. Southwest. Entomol. 2: 66-72.

Nine aerial applications of diflubenzuron, a boll weevil larval growth regulator, at rates of 0.03, 0.06, and 0.12 lb/A a.i. to 5-acre plots of cotton did not appear to adversely affect populations of beneficial arthropods. Also, in laboratory studies the parasitic wasp, Trichogramma pretiosum Riley, was not affected, but diflubenzuron was detrimental to 2 species of predators, the convergent lady beetle, Hippodamia convergens Guerin-Meneville, and the common green lacewing, Chrysopa carnea Stephens. Feeding and topical treatments at

5 ppm diflubenzuron reduced egg viability, larval survival, pupation, and adult emergence in C. carnea. Topical sprays (7.7 ppm) on H. convergens had similar effects, but both predatory species gradually recovered after treatments were terminated.

3. ; Jones, S. L.; House, V. S.; and Bull, D. L. 1980. Effect of diflubenzuron on entomophagous arthropods associated with cotton. Southwest. Entomol. Suppl. 1: 31-35

In laboratory studies, the insect growth regulator (IGR) diflubenzuron has been tested for harmful effects against several species of entomophages. While the IGR has no adverse effects on Geocoris punctipes (Say), Apanteles marginiventris (Cresson), and Trichogramma pretiosum (Riley), mortality of immature stages occurred in Hippodamia convergens Gueren-Meneville and Chrysopa carnea Stephens. However, the deleterious effects tended to subside if treatments were discontinued. Further laboratory and field studies showed that Savol, the parafinic crop oil with which the IGR is formulated, was toxic to some predators and reduced parasitism of Heliothis virescens (F.) eggs by T. pretiosum. Field studies have also demonstrated reduced populations of Geocoris and Nabis spp. in soybeans and Geocoris spp. in cotton. However, when applied to cotton at the recommended rate for field use, 70 g a.i./ha, diflubenzuron is much less harmful to populations of entomophagous arthropods than are most conventional insecticides.

4. Adair, H. M.; Kincade, K. T.; Laster, M. L.; and Brazzel, J. R. 1967. Low-volume aerial spraying of several insecticides for cotton-insect control. J. Econ. Entomol. 60: 1121-1127.

During 1965 and 1966, low-volume (LV) concentrate formulations of several insecticides or insecticide mixtures were evaluated for control of the bollworm, Heliothis zea (Boddie), and the boll weevil, Anthonomus grandis Boheman. Eight

LV formulations and 3 water-diluted emulsifiable concentrates were applied to 15- to 25-acre unreplicated plots with a Piper PA18A aircraft equipped with conventional boom, LV boom, and Micronair Rotary Atomizer application systems. The experiment was designed to compare the effectiveness of the LV materials with that of a standard treatment. Results in 1965 showed that the LV concentrate of the insecticides commonly recommended gave adequate control. These materials performed as well as the standard treatment. The undiluted materials that did not give satisfactory results at the rates used were Azodrin (3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate), azinphosmethyl, malathion-Abate (O, O-dimethyl phosphorodithioate O, O-diester with 4, 4'-thiodiphenol), malathion, and diazinon. In 1966, similar tests were conducted using essentially those materials found to be satisfactory in 1965. Results revealed that all the LV materials gave satisfactory control and were as effective as the standard treatment. Strobane (terpine polychlorinates (65% chlorine))-DDT-methyl parathion and Strobane-methyl parathion, both applied at 1/2 gal of concentrate/acre, appeared to be slightly more effective than the standard water-diluted treatment.

5. Adams, C. H., and Cross, W. H. 1967. Insecticide resistance in *Bracon mellitor*, a parasite of the boll weevil. J. Econ. Entomol. 60: 1016-1020.

The potential resistance to insecticides of *Bracon mellitor* Say was determined by treating each of 5 test groups for 5 or more generations with an organic insecticide commonly used for the control of cotton insects. Fourfold increases in tolerance were noted in groups treated with DDT, carbaryl, and parathion. A group treated with equal parts of DDT and toxaphene had resistance 8 times that of the original generation. Only a group treated with toxaphene alone showed no significant increase in tolerance. The results demonstrated that the parasite

has a mechanism for developing resistance to insecticides.

6. ; Cross, W. H.; and Mitchell, H. C. 1969. Biology of Bracon mellitor, a parasite of the boll weevil. J. Econ. Entomol. 62: 889-896.

Under optimum conditions in the laboratory, using 3rd-stage larvae of the boll weevil, Anthonomus grandis Boheman, for hosts, minimum life cycle averaged 11 days, average longevity of females was almost 22 days, and that of males was 10 days. The species was satisfactorily reared in the laboratory in the range of 21-29°C and 40-70% RH. Adult mortality rates increased sharply at lower levels of relative humidity. Females mated almost immediately after emergence. The egg was greatly contorted during oviposition and required 23-25 hours to hatch at 27-29°C. In a laboratory test, females deposited an average of 7.75 eggs per day or an average total of 164 eggs per female. They readily paralyzed and laid eggs on older boll weevil larvae; they rarely attacked pupae. Newly hatched larvae of the parasites were cannibalistic, limiting production per host material. Diapause and overwintering occurred in the prepupal stage. The overwintered generation was characterized by denser cocoons and black markings on the emerging adults. In the laboratory, relative humidity below 35% tended to induce diapause, and diapausing prepupae conditioned at 2-6°C for 2 weeks pupated and emerged as adults more promptly than when they were not thus cold treated. The release of adults at the rate of more than 800 females per acre of cotton per week in 1 field test increased parasitism from 0 to more than 50% in naturally falling boll-weevil-infested squares and to more than 80% in squares tied to the plants. This effect contrasts with the 25 and 35% maximum parasitism, respectively, observed in natural populations. Mass releases made periodically might produce effective control of boll weevisl. However, mass rearing has not been perfected.

7. Adkisson, P. L. 1973. Integrated control of the insect pests of cotton. Proc. Tall Timbers Conf. Ecol. Control Habitat Manage. 4: 175-188.

Short season cotton varieties promise to escape damage from the boll weevil. In addition, by maturing early - before the environment forces the boll weevil and pink bollworm into diapause - these cottons provide an "automatic" mechanism for reducing the numbers of these pests that are able to successfully prepare for the winter season. This is simply because these varieties may be harvested and plowed under so early that there should be no bolls or squares available for the development of diapausing individuals. The continued growing of the new cotton types over large geographic areas, combined with a regulated date for stalk destruction, promises to relegate the boll weevil and pink bollworm in Texas to the status of minor pests. In addition to the program in cotton breeding, state and federal entomologists in Texas also are seeking better methods for using insect pathogens, pheromones, selective insecticides, and modified cropping systems to maintain pest populations below damaging levels. The new system that will emerge will integrate pest population suppression practices in a compatible manner in order to optimize yields and producer profits. This should be the ultimate goal of any crop production program.

8. ; Rummel, D. R.; Sterling, W. L.; and Owen, W. L., Jr. 1966. Diapause boll weevil control: a comparison of two methods. Tex. Agric. Exp. Stn. Bull. 1054, 11 pp.

Insecticidal control of fall populations of boll weevils in the High and Rolling Plains during 1964 and 1965 made it possible to compare the relative effectiveness of two types of diapause control programs. Both programs dealt with reducing the overwintering boll weevil population. The 1964 program utilized six applications of malathion in an attempt to kill the potential overwintering adults during the feeding period after they had emerged from infested squares or bolls but before they had left the cotton fields for nearby

overwintering sites. This program produced a 90 percent reduction in the fall population. However, a great many weevils survived to infest the 1965 crop. The 1965 program combined control of the last reproductive generation of boll weevils in September with control of potential diapausing survivors in October and November. The 1965 program proved greatly superior to the 1964 program. The adult boll weevil population was reduced approximately 99 percent, and several times fewer weevils survived to enter hibernation than following the 1964 program.

9. Agee, H. R. 1967. Morphology of the central nervous system of the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae), and some electrophysiological techniques. Ann. Entomol. Soc. Am. 60: 779-783.

No morphological differences in the central nervous system were noted in laboratory-reared boll weevils, Anthonomus grandis Boheman, of a local strain, laboratory-reared weevils of Mexican origin, and field-collected weevils. Histological sections of the brain and ganglion showed that the cellular elements were situated around the periphery; the interiors of the ganglia were filled with nerve fibers. Sensory hairs on the tarsi and 7th and 8th abdominal segments are suitable sites for placement of glass micropipette electrodes, and leg and genital nerve bundles are suitable for use of silver-hook electrodes for electrophysiological studies of the receptors. Sharp-tipped metal microelectrodes can be inserted into the compound eye to study visual responses, and into the scape of the antenna to monitor sensory responses in the club of the antenna.

10. and Elder, H. W. 1970. Histology of the compound eye of the boll weevil. Ann. Entomol. Soc. Am. 63: 1654-1656.

A histological study of the compound eye of the boll weevil, Anthonomus grandis Boheman, with a light microscope showed that each eye is composed of about 500 ommatidia 100-140 μ in diameter at the lens, and 7 μ in diameter at the basement

membrane. A single ommatidium consists of a hexagonal lens, a crystalline cone, 4 Semper cells, 2 primary pigment cells, 6 secondary pigment cells, 6 retinula cells which contribute to the formation of a central rhabdom that extends from the Semper cells to the basement membrane, and 2 basal pigment cells that surround the base of the retinula cells. The 6 axons, 1 from each of the 6 retinula cells, join and penetrate the basement membrane as a bundle. Each bundle of primary nerves converges with other bundles to form larger bundles that enter the optic ganglion.

11. Anderson, D. M. 1968. Observations on the pupae of Anthonomus grandis grandis Boheman and A. grandis thurberiae Pierce (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 61: 125-129.

Typical pupae of the boll weevil, Anthonomus grandis grandis Boheman, from the southeastern United States were found to differ in certain respects from typical pupae of the thurberia weevil, A. grandis thurberiae Pierce from Arizona. The differences are found in the relative length of a pair of tubercles on the rostrum, in the number of well-developed setae on the posterolateral areas of the prothorax, and in the spacing of the setae on the anterolateral areas of the prothorax. A small portion of the specimens examined was observed to vary from the normal pattern of diferences. It was found possible to distinguish the sex of pupae of both kinds of weevil by the pair of lobes present near the anal opening in females. The lobes are not present in males.

12. Andrawes, N. R., and Dorough, H. W. 1967. Metabolic fate of carbaryl-naphthyl-C^{14} in boll weevils and bollworms. J. Econ. Entomol. 60: 453-456.

Adult boll weevils, Anthonomus grandis Boheman, were treated topically and bollworm, Heliothis zea (Boddie), larvae and adults were treated by injection with carbaryl-naphthyl-C^{14}. Hydrolytic as well as oxidative mechanisms were involved in the degradation of the carbamate in both species. Chloroform-

extractable metabolites tentatively identified were: 1-naphthol; 1-hydroxy-5, 6-dihydro-5, 6-dihydroxy-naphthalene; 5, 6-dihydro-5, 6-dihydroxy-1-naphthyl N-methylcarbamate; and 1-naphthyl N-hydroxymethylcarbamate. Unknown metabolites of a water-soluble nature were predominant in both insect species.

13. Angalet, G. W. 1964. Bracon greeni (Hymenoptera: Braconidae), a potential parasite of the boll weevil. Indian J. Entomol. 26: 447-452.

Bracon greeni Ashmead is an important parasite of certain pod-boring Lepidoptera in the Indian sub-continent, but attempts to introduce it into the United States between 1952-1957 as a natural control of the pink bollworm, Pectinophora gossypiella (Saunders), failed, possibly because of the difficulty encountered in breeding the parasite under laboratory conditions. As a result of evidence obtained in India that the parasite would accept a coleopterous host, tests were conducted at Moorestown, New Jersey, to determine whether the parasite would accept the boll weevil, Anthonomus grandis Boheman, as a host. These tests were successful. When last stage boll weevil larvae were used, some healthy F_2 adult B. greeni were obtained. Larvae of 5 other insects, also tested as hosts at Moorestown, were ignored by B. greeni.

14. Argauer, R. J.; Mason, H. C.; Corley, C.; Higgins, A. H.; Sauls, J. N.; and Liljedahl, L. A. 1968. Drift of water-diluted and undiluted formulations of malathion and azinphosmethyl applied by airplane. J. Econ. Entomol. 61: 1015-1020.

Deposits of undiluted technical formulations and water-diluted emulsifiable concentrates of malathion and azinphosmethyl applied by airplane were analyzed by chemical methods and by bioassay. The insecticides were detected under adverse conditions as far as 800 m (1/2 mile) downwind from the line of application. Estimated recoveries from the treated swaths and from the adjacent area into which the spray drifted ranged from 18 to 96% of the

calculated amount applied. Total recoveries of the undiluted formulations were consistently lower than those of the water-diluted emulsifiable concentrates.

15. Armenta, C. S. 1975. Evaluation of insecticides for control of the boll weevil in cotton in the "Valle del Fuerte," Sinaloa, Mexico. Folia Entomol. Mex. 33: 18. (In Spanish).

In test 1, Fustion at 1/ha and endrin at 292 gs + methyl parathion at 675 gs of active ingredient per/ha were the most effective against the boll weevil. In test 2, nuvacron at 450 gs/ha was more effective than endrin at 292 + methyl parathion at 675 gs/ha.

16. and Rodriguez, V. J. 1974. Seasonal fluctuations of arthropods in cotton plants in the "Valle del Fuerte," Sinaloa, Mexico. Folia Entomol. Mex. 28: 57-61. (In Spanish).

Weekly samplings were made in four cotton fields near the Agricultural Experiment Station of "Valle del Fuerte", Sinaloa, in order to know about the incidence of insect pests and beneficial insects. It was found that aphids occur during the first half of the plant cycle. The bollworm showed its highest incidence by the middle of April, while the boll weevil started to increase. Cotton leafperforator reached its highest levels starting early in June. Incidence of beneficial insects was higher during the last two weeks of April.

17. Armstrong, A. A.; Parker, R. D.; Walker, J. K.; Niles, G. A.; and Mulkey, J. R. 1980. A comparison of boll weevil damage (%) to bolls in different cotton genotypes. Southwest. Entomol. 5: 6-11.

Studies during 1975 and 1978 at Uvalde, TX indicated that the cotton variety TAMCOT SP-37 experienced a lower % damage to boll locks from boll weevils than several experimental cotton genotypes. A more rapid establishment of bolls earlier in the fruiting period may be responsible for this advantage in TAMCOT SP-37.

18. Ayer, W. A., and Browne, L. M. 1974. The transformation of carvone into racemic grandisol. Can. J. Chem. 52: 1352-1360.

Grandisol (1) is one of the components of the pheromone complex emitted by the male boll weevil. We report the transformation of readily available eucarvone (3), via the photoisomer 4, into grandisol in 20% overall yield. A key step in the synthesis is the Beckmann cleavage of oxime 15, derived in three steps from 4, to nitrile 16. Hydrolysis of 16 followed by hydride reduction gives grandisol (1).

B

19. Babler, J. H., and Coghlan, M. J. 1976. A facile method for the bishomologation of ketones to α,β-unsaturated aldehydes: application to the synthesis of the cyclohexanoid components of the boll weevil sex attractant. Synth. Commun. 6: 469-474.

The acid-catalyzed isomerization of tertiary vinyl carbinols to the corresponding primary allylic alcohols has been reported numerous times in the chemical literature. In addition, the corresponding acetylenic carbinols have been shown to rearrange to α,β-unsaturated aldehydes when treated with aqueous acid. Since yields are generally low under the conditions required for the latter transformation, a better method involves the isomerization of the corresponding tertiary acetylenic acetate in the presence of silver ion to an allenic acetate, followed by hydrolysis to the desired α,β-unsaturated aldehyde.

20. , and Mortell, T. R. 1972. A facile route to three of the four terpenoid components of the boll weevil sex attractant. Tetrahedron Lett. 8: 669-672.

J. H. Tumlinson, R. C. Gueldner, D. D. Hardee, A. C. Thompson, P. A. Hedin, and J. P. Minyard reported identification and synthesis of the four compounds (1, 2, 3, and 4) comprising the boll weevil sex attractant. These compounds are currently of considerable interest since they may provide a relatively nontoxic method of surveying and controlling the boll weevil population. This letter describes a facile route to the aldehyde components (1 and 2) in 60% overall yield. Separation of this mixture, followed by reduction of Z-aldehyde 1 with sodium borohydride, offers a route to the third component, Z-alcohol 3.

21. Bacheler, J. S., and Bradley, J. R., Jr. 1975. Effect of temperatures on development and mortality of the boll weevil egg stage. Environ. Entomol. 4: 319-320.

Anthonomus grandis Boheman egg development averaged 70.0, 56.7, 55.9, 73.9, 102.5, and 174.4 h at 36, 34, 30, 26, 22, and 18°C, respectively. Egg mortality was negligible within this temperature range. These data provide a missing component of boll weevil biology and are precise enough for computer simulation purposes.

22. ; Jones, J. W.; Bradley, J. R., Jr.; and Bowen, H. D. 1975. The effect of temperature on development and mortality of boll weevil immature stages. Environ. Entomol. 4: 808-810.

The developmental periods and mortality of the immature stages of field boll weevils at 18, 22, 26, 30, and 34°C were determined. Cotton branches containing squares into which a boll weevil egg had recently been deposited were placed into plastic Aquapics® in temperature controlled cabinets in which direct sunlight

was simulated. Abscised squares were transferred to chambers in which sub-canopy lighting was simulated. Sub-samples of squares were dissected and the stage of development and mortality recorded. The optimum developmental temperature for the North Carolina boll weevil strain was ca. 30°C, since mortality was at a minimum at that temperature and developmental times at 30° and 34°C were very nearly the same.

23. ; Jones, J. W.; Bradley, J. R., Jr.; and Bowen, H. D. 1975. Influence of temperature on abscission of cotton squares infested with boll weevil eggs. J. Econ. Entomol. 68: 298-300.

The mean time from egg deposition of the boll weevil, Anthonomus grandis Boheman, until square abscission at 5 selected temperatures ranged from 5.8 to 18.6 days at 34 to 18°C, respectively. At 26°C, ca. 1/2 of the squares remained on the plants longer than 7 days, suggesting that weekly sampling of squares as a basis for treatment decisions may be reflecting accrued in addition to current damage.

24. Bagga, H. S., and Laster, M. L. 1968. Relation of insects to the initiation and development of boll rot in cotton. J. Econ. Entomol. 61: 1141-1142.

Of the insects causing direct injury to the cotton boll, boll weevils, Anthonomus grandis Boheman; bollworms, Heliothis zea (Boddie); and tarnished plant bugs, Lygus lineolaris (Palisot de Beauvois), initiated boll rot infection. Initiation of boll infection by boll weevils ranged from 95% to 100%, by bollworms 55% to 80%, and by tarnished plant bugs 40% to 70%. Cotton bolls subjected to vinegar flies, Drosophila melanogaster Meigen, and cabbage looper moths, Trichoplusia ni (Hubner), developed nectary infections which in turn resulted in boll infection. Initiation of boll infection by vinegar flies ranged from 50% to 60%, and by cabbage looper moths 45% to 70%. Field-collected insects produced nearly as much infection as those held on the cultures of Alternaria

tenuis Auct. and Fusarium moniliforme Sheldon. No infection or rotting of the bolls was caused by either organism from contact inoculation.

25. Bailey, J. C.; Maxwell, F. G.; and Jenkins, J. N. 1967. Boll weevil antibiosis studies with selected cotton lines utilizing egg-implantation techniques. J. Econ. Entomol. 60: 1275-1279.

Two techniques of implanting eggs of the boll weevil, Anthonomus grandis Boheman, in cotton buds were used to compare antibiosis in 12 lines of Gossypium (7 G. hirsutum L., 1 G. arboreum L., 1 G. arboreum x G. hirsutum, 1 G. davidsonii Kellogg, 1 G. barbadense L., and 1 G. thurberi Todaro). Data obtained in greenhouse and field-cage studies included: boll weevil weights at emergence, days to emergence, number of buds, number of buds blooming out, size of buds (length and diameter), number of boll weevils from buds, and number of boll weevils from buds blooming out. Days required to develop and weights of adult weevils differed significantly between cotton lines within each test. Cotton lines showing antibiosis worthy of further study were: G. arboreum, G. thurberi, G. davidsonii, and 1 G. hirsutum (experimental line SA 13).

26. ; Maxwell, F. G.; and Jenkins, J. N. 1967. Mortality of boll weevils in squares of genotypically different lines of cotton. J. Econ. Entomol. 60: 1279-1280.

The mortality of immature forms of Anthonomus grandis Boheman, dissected from cotton squares from genotypically different lines of cotton, ranged from 10% to 53%. In both greenhouse and field tests the highest mortality occurred in the larval stage. Adult mortality was higher in field cages than in the greenhouse. Since the dead larvae had not fully consumed the available food and no proliferation of tissue or other physical aberrations were evident, death was probably caused by toxic substance(s), lack of proper nutrients,

or a feeding deterent in the squares that varied in concentration among the lines of cotton tested.

27. ; Maxwell, F. G.; and Jenkins, J. N. 1969. Influence of changes in the cotton plant during the season on the feeding, oviposition, and development of the boll weevil. J. Econ. Entomol. 62: 239-242.

Two varieties of cotton (Gossypium hirsutum L.), Deltapine Smooth Leaf (DPSL) and Acala 4-42-77, were studied 2 years to determine whether changes in the plant during the growing season might affect feeding, oviposition, and development of the boll weevil, Anthonomus grandis Boheman. The criteria used to measure the effects were the tests for antibiosis, feeding stimulant, and oviposition normally used to study host-plant resistance. The overall averaged results for 2 seasons showed no differences between varieties, but there were significant differences within test periods. This interaction between variety x test period indicated that testing is necessary through several periods of a season to determine true differences among varieties. In the test of feeding stimulants, the difference between squares collected at different dates was significant only after August 24, probably because there was less feeding on samples collected August 31 and September 7; the difference between varieties was not significant. In the studies of antibiosis made with lyophilized square powder diets there were no significant differences in time to eclosion of adults and weight of emerging weevils for samples collected weekly; thus, the time of the season that squares are collected should not affect results of a test of antibiosis.

28. ; Maxwell, F. G.; and Jenkins, J. N. 1972. Seasonal fluctuations in oviposition of the boll weevil in the laboratory. J. Kans. Entomol. Soc. 45: 242-254.

Oviposition of boll weevils, Anthonomus grandis Boheman, fed standard adult

diet plugs and maintained at a temperature of 31.1 ± 0.9° C and an RH of 55 ± 5% with 20 hr of light and 4 hr of darkness was measured for two 36-week periods. The data from the 2 periods did not agree, but they did indicate a seasonal fluctuation on weevil oviposition though the magnitude of this effect could not be determined.

29. Baker, D. N.. and Lloyd, E. P. 1970. Effect of age on respiration and transpiration in the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 63: 100-104.

Respiration and transpiration rates in A. grandis Boheman were measured with an open-system technique. Windspeed and humidity had no effect on respiration rate. There was an increase in metabolic activity, as indicated by the respiration rate, with age at temperatures above 35°C. The thermal death point in the boll weevil was fixed at 54 ± 2°C. There was a slight (2.5°C) increase with age in the thermal death point from 2 to 12 days. Indirect evidence of a spiracular response to high potential transpiration rates was obtained. There appears to be no systematic change in transpiration rate with age in the boll weevil.

30. , and Lloyd, E. P. 1970. An energy balance for the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 63: 104-107.

Respiration and transpiration by lots of 100 Anthonomus grandis Boheman (Coleoptera: Curculionidae), were measured in an open system under artificial lights at 3 levels (1.195, 0.530, and 0 calories per centimeter squared per minute) and at a wind speed of 134 centimeters per second. Using these data a table was constructed showing the relative magnitudes of the various elements of the energy budget for the insects. It was necessary to evaluate the reflectance and the thermal emissivity of the weevil; they were found to be 10.5% and 0.97%, respectively. It was found that the sum is by far the insect's greatest energy

source in nature. Most variation in short-wave radiation input is offset by changes in rate of convected heat loss. Latent heat losses amounted to 10% of the convected heat loss under bright light and up to 25% at light levels simulating cloud cover. It was concluded that because of the difficulty in estimating thermal radiant heat fluxes in nature, an accurate prediction of insect temperature from energy balance calculations would be impossible.

31. Baker, S. H., and Canderday, T. D. 1974. Registration of Georgia Super D cotton germplasm. Crop Sci. 14: 911.

Georgia Super D cotton (Gossypium hirsutum L.), a breeding line, was released to plant breeders in April 1973 by the University of Georgia Coastal Plain Experiment Station, Tifton, Georgia. Georgia Super D is unique in that it contains five genetically controlled characters that have shown resistance to boll weevil (Anthonomus grandis), bollworms (Heliothis sp.), and boll-rotting organisms. These characters are red plant color, frego bract, okra leaf, smooth leaf, and nectariless. The line is also homozygous for glandless stem (gl_1) and has reduced glands in seed and foliage (gl_2) but is not homozygous and a small percentage of plants with normal glands in foliage and seed can be found.

32. Bancroft, H. R.; Moore, C. A.; and Frazier, J. L. 1976. Development of a biochemical profile for mass-reared boll weevils (Coleoptera: Curculionidae). Comp. Biochem. Physiol. 53C: 9-12.

1. A simplified biochemical profile consisting of whole body levels of cholesterol, lipid, uric acid, and soluble protein was obtained on mass-reared Anthonomus grandis Boheman of three adult ages for 8 successive weeks representing four generations. 2. All parameters showed significant variation with adult age, sex, and chemosterilant treatment. 3. Levels of cholesterol, uric acid, and soluble protein were significantly depressed in weevils treated with busulfan. 4. The feasibility of obtaining biochemical data on large numbers of insects

as a means of quality control is verified, but the utility of this approach requires the long-term accumulation of such information prior to its application.

33. Barfield, C. S.; Bottrell, D. G.; and Smith, J. W., Jr. 1977. Influence of temperature on oviposition and adult longevity of Bracon mellitor reared on boll weevils. Environ. Entomol. 6: 133-137.

Adults of the parasite Bracon mellitor Say were held under constant temperatures (15.6, 21.1, 26.7, 32.2 and 37.8°C), day/night temperature extremes (37.8/15.6°C and 32.2/21.1°C) and 2 regimes simulating field temperatues. Daily oviposition and mortality data were collected and used to calculate "capacity for increase" (r_e), net reproductive rate (R_o), mean generation time (T_e) and finite rate of natural increase (λ). Values of r_e increased with temperatues from 15.6-32.2°C, then rapidly fell to zero as no adults survived to oviposit at 37.8°C. The large increase observed between 15.6 and 21.1°C was evidence for a minimum threshold effect. Generally, r_e was not significantly higher at variable temperatues, and a maximum r_e value of 0.26 occurred at a constant temperature of 32.2°C and under one of the field simulations. Adult longevity decreased with increasing temperature from a mean of 99.2 days at 15.6°C to a mean of 7 days at 37.8°C. Females lived shorter lives under the variable temperature regimes.

34. Bariola, L. A., and Lindquist, D. A. 1970. Longevity and fecundity of boll weevils exposed to sublethal doses of systemic insecticides. J. Econ. Entomol. 63: 527-530.

Four systemic insecticides, disulfoton, dicrotophos, monocrotophos, and aldicarb were evaluated for their effect on the longevity and fecundity of Anthonomus grandis Boheman. Weevils were exposed continuously to 2 treated substrates: (1) filter paper treated with the toxicants and (2) excised cotton leaves that had taken up known amounts of the toxicants through

the petioles. Mortality increased with time and increased doses. Also, the rate of oviposition decreased during a 19-day period when the weevils were continuously exposed to sublethal doses of the insecticides; greater reductions occurred at higher doses. In all tests, aldicarb affected mortality and fecundity more than other insecticides.

35. ; Ridgway, R. L.; and Coppedge, J. R. 1971. Large-scale field tests of soil applications of aldicarb for suppression of populations of boll weevils. J. Econ. Entomol. 64: 1280-1284.

In-furrow and sidedress applications of aldicarb were compared with foliar applications of azinphosmethyl for suppression of populations of Anthonomus grandis Boheman in an area near the Texas High Plains boll weevil control zone. The applications of aldicarb reduced populations of adult boll weevils 94-96% until long-range movement of weevils began in late August. Meanwhile, 4 applications of azinphosmethyl reduced populations only 73%. Some increase in populations of Heliothis spp. occurred in most plots treated with an insecticide; however, the greatest increases occurred in those treated with sidedress applications of aldicarb.

36. Bartlett, A. C. 1968. Behavior of irradiated boll weevils. II. Reproduction and mortality in cages with untreated boll weevils. J. Econ. Entomol. 61: 1680-1684.

Mortality, egg production, and egg hatch were determined for female Anthonomus grandis Boheman which had been treated with 6388 or 12775 rad of gamma irradiation and confined in various ratios with treated and/or untreated male and female weevils of the same age and strain. Both treatments sterilized the weevils, but egg hatch was reduced only when the ratio of treated (T) to normal(N) male weevils exceeded 10T:1N. When the treated group consisted of males only

or males and females and the ratios were 20T:1N or 100T:1N, hatch was reduced. However, groups of treated females only had no effect on hatch at any ratio of treated to normal weevils. In a 35-day test, 4 weekly releases of irradiated weevils to maintain a cage population ratio of 100T:1N caused a reduction in hatch ranging between 70 and 90%.

37. . 1968. Genetic markers in the boll weevil. J. Hered. 58: 158-163.

Four new mutations for the boll weevil, Anthonomus grandis, are described. Two, slate (s) and ebony (e), are body color genes exhibiting semidominant autosomal inheritance. Both of these genes, in the homozygous state, produce black body color. In the heterozygous state, ebony produces a bronze color, and slate produces a dark red color compared to the red wild-type color. Two are recessive autosomal eye color genes. Pearl (p) produces a white spectacled appearance of the eyes. The second eye color mutation produces yellow eyes and is called yellow (y). Linkage relationships of these genes are at present undetermined. Genetic markers such as those described in this paper should be of value in entomological research. Such mutants meet most of the conditions required of marking methods. Searches for mutants in other insect species should be made for use both as biological markers and for use in biological control.

38. ; Hooker, P. A.; and Hardee, D. D. 1968. Behavior of irradiated boll weevils. I. Feeding, attraction, mating, and mortality. J. Econ. Entomol. 61: 1677-1680.

The feeding activity, mating frequency, attraction, sexual response, and mortality of normal Anthonomus grandis Boheman were compared with boll weevils irradiated with 6,388 or 12,775 rad of Co^{60} gamma radiation. The irradiated weevils equaled normal weevils in each aspect of behavior for at least 5 days posttreatment. However by the 7th day posttreatment, all these activities had started to decline in the treated weevils and all irradiated weevils were

dead by the end of the 2nd week. Thus, irradiated boll weevils may be effective in a program involving the release of sterile insects, but the releases would have to be made at least weekly and preferably every 5 days.

39. ; Mattix, E. B.; and Wilson, N. M. 1968. Multiple matings and use of sperm in the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 61: 1148-1155.

Virgin female boll weevils, Anthonomus grandis Boheman, from a mutant strain with pearl-colored eyes were mated in various combinations to males of the same pearl strain or to males with brown (wild-type) eyes to study the use of sperm in multiple matings. Sperm from the last mating took precedence over sperm from other matings only when at least 24 hours separated the matings. The advantage of sperm from the last mating ranged from about 10% when 1 day separated matings to 90% when 4 days intervened. This advantage lasted from about 7 days when the interval between matings was short to more than 45 days from the longest interval. It is concluded from other data that most field females will follow the pattern of sperm use shown by closely spaced multiple matings.

40. , and Mitlin, N. 1967. Developmental and reproductive effects of heavy water (D_2O) in the diet of the boll weevil. J. Econ. Entomol. 60: 647-655.

The substitution of various concentrations of heavy water (D_2O in place of H_2O) in the adult and larval diets of the boll weevil, Anthonomus grandis Boheman, showed that: (1) levels of heavy water above 60% of the total water incorporated into the adult diet reduce egg production in the treated females, but the action is quickly reversible when normal food is restored; fertility in treated individuals is not affected; (2) as the percentage of heavy water is increased in the larval diet (a) the percentage of eggs developing in the treated diet

decreases, (b) the rate of development, measured by pupation time, decreases; that is, developmental time increases, (c) the weight of developing larvae, and even pupal weight, is decreased and (d) addition of amount of D_2O greater than 50% of the total water completely inhibits larval development; (3) levels of heavy water above 35% in the larval diet result in the sterility of at least 89% of the insects reared on the diet, causing a decrease in egg production, regardless of the sex treated, plus an increase in the time required for maturity. If the use of D_2O can be perfected, the laborious handling of individual weevils in a sterile-release program might be eliminated.

41. Beck, S. D., and Maxwell, F. G. 1976. Use of plant resistance. In C. B. Huffaker and P. S. Messenger (eds.), Theory and Practice of Biological Control, pp 615-636. Academic Press, New York.

Probably more is currently known about biologically active materials in the cotton plant that affect the behavior of the boll weevil than for any other insect - host situation. A program was begun in 1962 at the USDA Boll Weevil Research Laboratory at State College, Mississippi, to determine some of the factors involved in the selection (host preference) of cotton and other alternate hosts of the boll weevil. The following briefly describes progress made by a number of researchers over the past 9 years.

42. Beckham, C. M. 1970. Control of cotton insects with ultra-low-volume sprays. J. Ga. Entomol. Soc. 5: 78-82.

Field experiments were conducted in 1968 and 1969 to evaluate different insecticide formulations applied by ground equipment to cotton as ULV sprays for control of the boll weevil, Anthonomus grandis Boheman; bollworms, Heliothis spp.; and spider mites, Tetranychus spp. The insecticides tested were: toxaphene + methyl parathion; malathion + methyl parathion; C-9491 (0-(2,5-dichloro-4-iodophenyl) 0,0-dimethyl phosphorothioate); BCS-506 (0-(2,5-dichloro-4-bromophenyl)

O-methyl phenylthiophosphonate); Azodrin® (3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate); BAY 77488 (0,0-diethyl phosphorothioate O-ester with phenylglyoxylo-nitrile oxime); and malathion + AC 47470 (P,P-diethyl cyclic propylene ester of phosphonodithioimidocarbonic acid). The use of the sprays resulted in varying degrees of control among the insecticides, but in most instances infestations of, and damage by, the pest species were reduced and yields of cotton were increased.

43. . 1970. Effect of nitrogen fertilization on the abundance of cotton insects. J. Econ. Entomol. 63: 1219-1220.

Tests were conducted from 1964 to 1966 to determine the effect of different rates of nitrogen sidedress applications on the abundance of and damage from cotton insects in nonirrigated cotton under a seasonal insecticidal control program. Insect infestation or damage counts were made on the boll weevil, Anthonomus grandis Boheman; bollworm, Heliothis zea (Boddie); and the cotton aphid, Aphis gossypii Glover. The insecticidal spray programs resulted in effective control of boll weevil and bollworm during each of the 3 years. Significant differences in boll weevil square infestation caused by the different treatments of nitrogen were obtained only 1 year. Significant differences in bollworm damage to bolls did not occur among treatments with nitrogen during any of the 3 years. Although there was an indication that more aphids occurred on leaves as the rate of nitrogen was increased, significant differences among treatments were obtained only 1 year. The effects of nitrogen sidedress applications on the yield of seed cotton per acre were inconsistent.

44. , and Tippins, H. H. 1966. Status of boll weevil resistance in relation to changing insecticide control program, 1960-65. J. Ga. Entomol. Soc. 1: 1-4.

Boll weevil, Anthonomus grandis Boheman, susceptibility to endrin and methyl

parathion, following a change in the field from the use of chlorinated hydrocarbon to organophosphorus insecticides, was determined by topical treatment of four weevil populations. Three of the populations, originally resistant to endrin, continued to exhibit resistance to this insecticide after 5 years. However, there was a trend toward a lowering of the LD-50 values. An endrin-susceptible population showed a consistent increase in the LD-50 but is still considered susceptible to endrin. The response to methyl parathion was essentially the same among the population during the 4 years and no resistance to this insecticide is suspected.

45. Becton, A. J. 1972. Summary of research conducted with GS-13005 (Supracide R) for control of cotton pests in the Cotton Belt of the United States. Folia Entomol. Mex. 23-24: 26-27. (In Spanish).

Data from eleven trials where GS-13005 was evaluated for Anthonomus grandis Boheman control are presented. These data indicate that GS-13005 at 1 lb ai/acre was comparable to Toxaphene + DDT at 2 + 1 lbs ai/acre and Guthion at 1/4 and superior to methyl parathion at 1/4.

46. Bedoukian, R. H., and Wolinsky, J. 1975. A biogenetic-type synthesis of the cyclohexyl constituents of the boll weevil pheromone. J. Org. Chem. 40: 2154:2156.

Treatment of the acid chloride of geranic acid with triethylamine and methanol affords methyl γ-geranate contaminated by ca. 10% of methyl geranate. Acid-catalyzed cyclization of methyl γ-geranate affords, in high yield, a mixture composed primarily of methyl 3,3-dimethylcyclohexenylacetates (12 and 13). The endocyclic unsaturated isomers 12 and 13 were converted to the desired conjugated, exocyclic isomers 15 and 16 by addition of hydrogen bromide followed by dehydrobromination with triethylamine. Lithium aluminum hydride reduction of 15 and 16 gave (Z)- and (E)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol

(2 and 2a), which, in turn, were converted into the corresponding aldehydes by oxidation with manganese dioxide.

47. Bell, M. R., and McGovern, W. L. 1975. Susceptibility of the ectoparasite, Bracon mellitor, to infection by microsporidan pathogens in its host, Anthonomus grandis. J. Invertebr. Pathol. 25: 133-134.

Since boll weevil larvae are used as hosts for rearing B. mellitor, a study was made to determine possible effects of G. gasti and an unidentified microsporidan on the parasite. The results of the study showed that infection of a host colony by G. gasti would have an adverse effect on B. mellitor rearing; infection with the unidentified microsporidan would apparently have little or no effect.

48. , and McLaughlin, R. E. 1970. Influence of the protozoan Mattesia grandis McLaughlin on the toxicity to the boll weevil of four insecticides. J. Econ. Entomol. 63: 266-269.

Anthonomus grandis Boheman, infected with the protozoan Mattesia grandis McLaughlin, were more susceptible to lower doses of malathion, azinphosmethyl, DDT, or carbaryl as the numbers of protozoans multiplied in the weevils. Thus, the toxicity of all 4 insecticides to the weevils increased as the disease progressed, and by the 12th day postinfection, the LD_{50} values had decreased 5- to 7-fold. Also, fat content of the infected weevils decreased as the disease progressed, and little or none remained at 12 days postinfection.

49. Benedict, J. H.; Bird, L. S.; and Liverman, C. 1979. Bacterial flora of MAR cottons as a boll weevil resisting character. Proc. 1979 Beltwide Cotton Prod. Res. Conf., pp. 228-230.

Based on these experiments and others, we concluded the following: (1) Some cotton genotypes favor larger populations of certain normal flora micro-organisms

than other genotypes; (2) the composition of normal flora can affect boll weevil feeding and egg laying preference; (3) normal flora composition in some cotton genotypes can be artificially manipulated by inoculation, to increase boll weevil resistance; (4) certain species of Bacillus and Pseudomonas in cotton normal flora are major contributors to the boll weevil resistance mechanism; (5) boll weevil resistance due to certain normal flora compositions is reflected in; (a) increased earliness in fruit set and development, (b) increased number of total bolls, and (c) increased yield compared to an isogenic check containing a different normal flora composition.

50. , and George, D. M. 1979. A bibliography of host plant resistance literature for the boll weevil, Anthonomus grandis. Bull. Entomol. Soc. Am. 25: 19-23.

Our purpose is to provide research scientists, interested in host plant resistance to the boll weevil, with a bibliography which is as complete and up-to-date as humanly possible. The literature cited includes proceedings, technical, and popular articles. Several publications dealing with boll weevil behavior, natural mortality, and laboratory culture are also included to better acquaint the scientist with the complexity of this plant-pest system. Host plant resistance is by nature an integrative science; the effects of weather, soil, natural enemies, and the genetics of both host plant and insect herbivore form a constellation of interactive factors which controls pest behavior and survival, and ultimately, crop yield. These factors must be considered if host plant resistance studies on the boll weevil are to be meaningful.

51. Betz, N. L. 1966. Improved laboratory methods for rearing the boll weevil. J. Econ. Entomol. 59: 374-376.

A disposable bacteriological capillary tube provided a simple and gentle method of implanting eggs of the boll weevil, Anthonomus grandis Boheman,

onto artificial diet. The technique is equally adaptable to maintenance of small cultures and to mass-rearing programs. Eggs were collected from cotton squares (flower buds) by chopping the squares in water with a household food chopper. The eggs were removed, surface sterilized, and submerged in sterile water in a sterile petri dish. The egg-water suspension was drawn into a disposable bacteriological capillary tube and ejected onto the scratched surface of larval diet in petri dishes. The petri dishes containing the eggs and diet were held 14-17 days at 26°C for development, after which the adults were removed and held in cartons for feeding and egg production. The moisture content of diet before eggs were implanted was the most important of the conditions investigated in determining the percentage of adults that were obtained.

52. , and Lambremont, E. N. 1967. Changes in stored glycogen and lipids associated with diapause of the adult boll weevil, Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 60: 866-868.

Increases in glycogen and lipids are known to take place as newly emerged adult boll weevils feed and undergo diapause development. This process is generally assumed to represent storage of important nutrient reserves which are drawn on when feeding is no longer possible during the overwintering period of diapause. The present communication reports the results of some preliminary experiments made to determine whether the adult weevil preferentially depletes its carbohydrate reserves before degrading its lipids or whether both decrease simultaneously.

53. ; Nettles, W. C., Jr.; and Novak, A. F. 1968. Physicochemical characteristics of glycogen from Anthonomus grandis. Comp. Biochem. Physiol. 24: 163-175.

Glycogen was extracted from the boll weevil, Anthonomus grandis Boheman, with 5% trichloroacetic acid (TCA) and with cold chloroformglycine buffer (cold

water extraction). Glucose was the only sugar detected in acid hydrolyxates. The average chain lengths, as determined by methylation, hydrolysis, silanization and gas-liquid chromatography, were 11.0, 11.9, and 11.8 glucose units, respectively, for glycogen extracted with cold water from eggs and larvae and glycogen extracted with TCA from larvae. The high percentage (82) of 2,3,6-trimethylglucopyranose obtained indicated that the principal linkage between glucose units was 1,4. Similar i.r. spectra were obtained from glycogens extracted with TCA and cold water. Boll weevil glycogen complexes with iodine-iodide gave absorption spectra similar to a rabbit liver glycogen standard. The optical rotation of glycogen extracted with TCA from larvae was +200·0°. Measurements of optical rotation could not be made of material extracted with cold water because of high opalescence.

54. Biggers, C. J., and Bancroft, H. R. 1976. Inheritance of hemolymph esterases of the cotton boll weevil (Anthonomus grandis Boh.). J. Tenn. Acad. Sci. 51: 59.

Four esterase regions from boll weevil hemolymph were demonstrated by vertical polyacrylamide gel electrophoresis. They were designated Esterases I, II, III, and IV in order of anodal migration. The inheritance pattern for Esterase II was determined by a series of laboratory matings. The evidence suggests that the esterases in this region are controlled by a pair of autosomal codominant alleles.

55. , and Bancroft, H. R. 1977. Esterases of laboratory-reared and field-collected cotton boll weevils, Anthonomus grandis Boh.: polymorphism of adult esterases and formal genetics of Esterase II. Biochem. Genet. 15: 227-233.

The esterases of the cotton boll weevil were separated by polyacrylamide gel electrophoresis into four major regions. These were named Est I-IV in order of migration from anode to origin. Polymorphism was observed in all regions. The Est II region was shown to consist of no more than two bands (fast and slow). The inheritance of the fast and slow bands of Est II was demonstrated to be controlled by codominant autosomal alleles. Analysis of the gene frequency of the Est II region showed that one field population was consistent with the Hardy-Weinberg law (P=0.995), while a second field population was not at equilibrium ($P < 0.001$).

56. Birch, M.; Trammel, K.; Shorey, H. H.; Gaston, L. K.; Hardee, D. D.; Cameron, E. A.; Sanders, C. J.; Bedard, W. D.; Wood, D. L.; Burkholder, W. E.; and Muller-Schwarze, D. 1975. Programs utilizing pheromones in survey or control. Frontiers of Biol., Pheromones 32: 411-461. North Holland Pub. Co., Amsterdam, Netherlands.

Clearly pheromones are no panacea for pesticide plagued agriculture. They are still not available for regular use, but their promise for practical use in the near future has not diminished. Whether pheromones prove to be of agricultural value as a control technique, or not, their study should produce a lot of valuable biological information about pest species and their use as a survey tool is already of great value. Pheromones will probably take their place, along with other new techniques, as part of a broad spectrum of control strategies to provide additional and optional inputs into the pest control decision making apparatus. The future emphasis will be on a multi-faceted approach with flexibility as the key note. Research with pheromones is reviewed for the redbanded leafroller, cabbage looper, pink bollworm, boll weevil, gypsy moth, and spruce budworm.

57. Bird, L. S.; Benedict, J. H.; Bourland, F. M.; Reyes, L.; Bush, D. L.; and Percy, R. G. 1977. Breeding glandless cottons for disease and insect resistance. In Glandless Cotton. Its Significance, Status, and Prospects. Proceedings of a Conference, December 13-14, 1977, Dallas, Texas, pp. 124-140. U.S. Agricultural Research Service, New Orleans.

Developing cottons having disease and insect resistance has been a serious challenge for many scientists working with cotton. Meeting the challenge in glandless cottons will give double dividends for a crop that provides fiber and food with no limitations on use. Current trends concerning energy, the use of pesticides, pollution standards and world food protein needs inject a sense of urgency for researching glandlessness in cotton. Disease and insect resistant glandless cottons will permit more economical production of the basic raw materials cellulose, food protein, oil and roughage in management systems which are efficient in using energy and natural resources. Hindsight must be used in planning for the future. Considerable information is available for genetic improvement for disease resistance and the pool of knowledge for insect resistance is accumulating daily. The good and bad experiences from many years of disease resistance research can be used to make improvement for insect resistance more effective. We will give an analysis of the past and present as a basis for emphasizing a plan for developing disease and insect resistant glandless cottons.

58. Bird, T. G., and Bancroft, H. R. 1976. The effects of Ciba-Geigy synthetic juvenile hormone on fecundity and total sterol levels in the cotton boll weevil, Anthonomus grandis Boheman. J. Tenn. Acad. Sci. 51: 60.

Ciba-Geigy 13353, a compound with juvenile hormone properties was topically applied at 50 and 75 microgram levels per insect to the cotton boll weevil. Observations on egg production were taken at 4 adult ages. Sterol level were

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determined at day 1 to determine carry-over from the pupal stage to the adult and at day 7 upon termination of all tests. Response to treatment was statistically significant in reduction of egg production and in reduction of total sterol as compared with appropriate control insects.

59. Bonham, C. D., and Fye, R. E. 1971. An empirical model for predicting boll weevil distribution on cotton plants. J. Econ. Entomol. 64: 539-540.

Several sampling schemes can be implemented to determine boll weevil infestation levels in a given field. For example, sampling of contiguous plants and recording presence or absence of insects on a given plant would give an estimate of % of plants infested. Sampling (checking of plant for insects) should consider the region of the plant which gives close estimates of the model. For example, the top 6 in. of the plant. Thus, letting N_b=estimated number of boll weevils per acre; P=proportion of plants with one or more individuals in percent; N_p= estimated number of boll weevils per infested plant; N_a=number of plants per acre; X_1=number of the 6-in. increment from the top of the plant where the observations were made (= the i th observation); n_1=number of insects of i th observation; Y_j=expected frequency of insects at the j th distance, as obtained from equation 1, we can estimate infestation levels in a given field. If X_1 is the region of interest and a mean value is used for n (i.e., n) based on a sufficient sample, values of Y_1 and N_b will be close to their true population values. The value of Y_j given X_i is obtained from (3) and $N_p = n/Y_j$; $N_b = (N_a)\ (P)\ (N_p)$ is the estimated infestation level for the field. The estimate is clearly related to the distribution of the insect population on plants throughout the field and should be considered in designing field sampling plans.

60. Borkovec, A. B. 1975. Chemosterilization of the boll weevil. Chemosterilant News (India). 2: 3-8.

An integrated approach to the containment or elimination of the boll weevil,

Anthonomus grandis Boheman, includes the release of sexually sterile weevils into cotton fields when population densitities of the pest are low. Therefore, sterilization of this insect is of considerable practical importance and numerous techniques for achieving the goal were explored. One of the oldest and still most promising techniques is chemosterilization and thousands of candidate compounds were evaluated as potential chemosterilants. The principal requirement for a suitable sterilant is a high organ specificity that would cause permanent sterility in both sexes of the weevil and minimal damage to the vigor and longevity of the male. At present only certain alkylating agents are known to have such effects and new methods of applying them to laboratory-reared weevils are being developed. The mechanism of action of alkylating sterilants involves direct interaction between the compound and the reproductive organs or the gametes. However, other types of sterilants that interfere with various regulatory processes can also be utilized particularly in combination with alkylating agents.

61. , and McHaffey, D. G. 1977. Chemosterilization of the boll weevil by fumigation. J. Econ. Entomol. 70: 424-426.

Fumigation of adult Anthonomus grandis Boheman at atmospheric pressure with alkylating aziridinyl phosphine sulfides and oxides or with nonalkylating dimethylamino phosphorus amides induces sterility in both sexes. Lowest mortality and complete sterility of both sexes were obtained when the fumigant was a mixture of P,P-bis(1-aziridinyl)-N-methylphosphinothioic amide and hempa. The fumigation was performed at 30°±1°C in a 4-liter stainless steel vessel furnished with a fan driven by an external motor. At an exposure period of 2.5 h, the sterility of males and females was 100 and 99.9%, respectively; mortality of treated weevils was ca. 40% at 8 days posttreatment. The procedure is simple and applicable to mass treatment.

62. ; Woods, C. W.; and McHaffey, D. G. 1972. Chemosterilants against the boll weevil. 1. Aziridines. J. Econ. Entomol. 65: 1543-1547.

Of 141 aziridinyl compounds tested against Anthonomus grandis Boheman, 56 had sterilizing activity when added to the insect diet. The most reliable indicator of effectiveness was a reduction in oviposition that persisted when treated males were crossed with untreated females. The most effective compounds were substituted bis(1-aziridinyl) phosphine oxides and sulfides, but the relatively high activity of substituted 1-aziridineethanols and other compounds indicated that the structure-activity relationships determined for this class of sterilants in the house fly, Musca domestica L., were not applicable to A. grandis.

63. ; Woods, C. W.; and Terry, P. H. 1978. Boll weevil: chemosterilization by fumigation and dipping. J. Econ. Entomol. 71: 862-866.

A procedure suitable for sterilizing both sexes of Anthonomus grandis grandis Boheman on a large scale was developed. First, the weevils were fumigated with bisazir (P,P-bis(1-aziridinyl)-N-methylphosphinothioic amide, AI3-61585) at atmospheric pressure for 90 min, and 30 min later, they were dipped for 5 sec into a 1.35% solution of penfluron (2,6-difluoro-N-[[[4-trifluoromethyl) phenyl]amino] carbonyl]benzamide, AI3-63223) in acetone. In either sex, the sterility exceeded 99%, and 59.3% of the treated males survived 10 days posttreatment. A new laboratory-size fumigation chamber with a rotating bisazir-treated paddle was designed and scaled up to a field-size chamber suitable for treating up to 200,000 weevils at a time. Monitoring of the sterilizing treatment consisted of measuring the concentration of bisazir vapors during the fumigation and analyzing the treated weevils for residues of bisazir and penfluron. One day posttreatment, no residues of bisazir or of its aziridinyl metabolite could be detected in the treated weevils, but penfluron residues decreased

only slowly from 39 to 8.8 μg/weevil within 7 days. Oviposition of untreated females mated to treated males was decreased; also, treated males were less effective than untreated ones in transferring sperm. On the other hand, when various ratios of treated and untreated males were combined with untreated females, the treated males appeared more competitive because they suppressed reproduction more effectively than their proportional number would warrant. The development of the new sterilizing procedure now makes it possible to test the performance of chemosterilized weevils in large field tests.

64. Bottrell, D. G. 1968. Comparative effectiveness of malathion and azinphosmethyl applied as ultra-low-volume sprays in a fall boll weevil control experiment. Tex. Agric. Exp. Stn. Prog. Rep. PR-2543, 7 pp.

Two rates of each malathion and azinphosmethyl were applied six times as ultra-low-volume aerial sprays in a fall boll weevil control experiment in Stonewall County, Texas. Azinphosmethyl at the rate of 0.25 pound active toxicant per acre provided slightly more effective weevil control than azinphosmethyl at 0.19 pound per acre. The lower rate of azinphosmethyl was about equal in effectiveness to malathion at 1.21 pound per acre. Percentage diapause in weevils remaining at the end of the experiment was about the same in all four treatments.

65. . 1973. Using grandlure to manipulate overwintered boll weevil populations into restricted sites within cotton fields. Folia Entomol. Mex. 25-26: 74-75. (In Spanish).

Results from research conducted in the Rolling Plains of Texas, 1971, demonstrated a principle of using glandlure, the synthetic pheromone of the male boll weevil, Anthonomus grandis Boheman, to manipulate adult overwintered populations of the species into restricted sites within cotton fields through use of traps baited with grandlure.

66. . 1976. Biological control agents of the boll weevil. In Boll Weevil Suppression, Management, and Elimination Technology. Proc. of a Conf. February, 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 22025.

More is known about the boll weevil's insect and mite parasites than about its other natural enemies. Forty-two species of arthropod parasites have been recorded by Cross and Chestnut as attackers of the pest. Among the more effective native species of parasites are Bracon mellitor Say in the United States, and Heterolaccus grandis Burks in western Mexico and Central America. Few pathogens have been observed to attack the boll weevil under natural conditions, but recent observations suggest that certain pathogens might have tremendous potential as control tools if they could be augmented safely and economically.

67. . 1976. The boll weevil as a key pest. In Boll Weevil Suppression, Management, and Elimination Technology. Proc. of a Conf., February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 5-8.

What would be the expected behavior of Heliothis in an all-out beltwide elimination attempt which would rely on more insecticide applications than those now being used? Isn't it possible that the boll weevil applications would be counteractive? That is, would they not possibly create a resistant Heliothis, a problem far more serious than that of the boll weevil? Furthermore, does it not appear highly likely that the severe insecticde pressure on the weevil throughout its complete range in the United States, which an alimination effort would require, would increase the chances of an organophosphorus-resistant strain appearing in the U.S. population? True, the pest is currently under tremendous selection pressure in many areas of the United States. But we also must remember that much weevil-infested cotton in the United States is currently not being treated at all, which

means that selection pressure across the Cotton Belt would be greatly increased during the insecticidal phases of an eradication attempt. There is no doubt that complete beltwide elimination of the boll weevil as a key pest would be a giant stride for North American agriculture. On the other hand, a beltwide attempt at elimination which was anything less than completely successful could result in the fabrication of an organophosphorus-resistant "superduper" pest.

68. , and Adkisson, P. L. 1977. Cotton insect pest management. Annu. Rev. Entomol. 22: 451-81.

Although most discussion of integrated control and pest management center on the developments of the past decade, the genesis of ecologically oriented pest control actually taces back to the late nineteenth and early twentieth centuries. Truly great historical figures of American entomology such as R. V. Riley, J. H. Comstock, L. O. Howard and W. D. Hunter were among those who molded the foundations of modern insect pest management as it is recognized in cotton and other agricultural crops today. The first boll weevil management system was fully developed and tested by 1920. The recent trend toward more sophisticated insect pest management, which embraces as a primary component the utilization of natural manipulatable factors, is a mere revival of the application of concepts that were well advanced by the early part of this century.

69. , and Almand, L. K. 1968. Evaluation of the 1967 reproductive-diapause boll weevil control program of the Texas High Plains. Tex. Agric. Exp. Stn. Misc. Publ. MP-904, 4 pp.

The 1967 High Plains reproductive-diapause boll weevil control program was initiated September 8 and terminated November 7. A total of 501,024 acres of cotton was sprayed with aerial applications of ultra-low-volume malathion and

azinphosmethyl insecticide to control fall populations of the boll weevil, Anthonomus grandis Boheman. The eight-county control zone contained approximately 60 percent fewer acres infested with weevils in 1967 than in 1964. The potential overwintering weevil population in the control zone in 1967 was estimated to be 85.6 percent smaller than in nearby untreated fields. An estimated eight weevils per acre were found in April 1968 in hibernation sites near treated fields. That compared to 484 weevils per acre in sites near untreated fields.

70. , and Almand, L. K. 1969. The effects of reproductive-diapause boll weevil control programs on populations of the bollworm and the tobacco budworm in cotton, 1968. Tex. Agric. Exp. Stn. Prog. Rep. PR-2702; pp. 1-6.

In the spring and summer of 1968, larval populations of the bollworm, Heliothis zea (Boddie), and tobacco budworm, Heliothis virescens (F.), were about equal in size in cotton fields which were sprayed with malathion insecticide for boll weevils, Anthonomus grandis Boheman, in the fall of 1967 and in fields not sprayed in 1967. But in the fall of 1968, after cotton had received several aerial applications of either ultra-low-volume (ULV) malathion or azinphosmethyl (Guthion®), more bollworms and tobacco budworms were present in treated fields than in check fields. The fall bollworm-budworm populations in treated fields apparently increased after the insecticide treatments killed many beneficial insects which held the pests in check in untreated fields.

71. , and Almand, L. K. 1970. Evaluation of the 1968 reproductive-diapause boll weevil control program of the Texas High Plains. Tex. Agric. Exp. Stn. Prog. Rep. PR-2766, 15 pp.

Beginning September 3, a total of 616,629 acres of cotton was sprayed by aircraft under the supervision of the Plant Protection Division, Agricul-

tural Research Service, U.S. Department of Agriculture. This initiated the 1968 High Plains reproductive-diapause boll weevil control program. Ultra-low-volume malathion and azinphosmethyl (Guthion®) insecticide was applied to control fall populations of the boll weevil, Anthonomus grandis Boheman. When the last insecticide application was completed November 5, treated cotton fields being monitored in Kent County (the most heavily weevil-infested county in the control zone) averaged an estimated 2,360 potential overwintering weevils per acre as compared with 4912 potential overwintering weevils per acre in untreated check, cotton fields in Stonewall County. In January 1969, an estimated 2,299 weevils per acre were present in hibernation sites near cotton fields treated in the 1968 program in Dickens and Kent Counties as compared to an estimated 11,374 weevils per acre in sites near untreated cotton fields in Stonewall County.

72. ; Arnold, D. M.; and Almand, L. K. 1968. Effects of reproductive-diapause boll weevil insecticidal programs on the abundance of bollworm and tobacco budworms in the Rolling Plains of Texas, 1967. Tex. Agric. Exp. Stn. Prog. Rep. PR-2627, 10 pp.

Cotton sprayed in the fall with aerial applications of ultra-low-volume (*ULV) malathion and azinphosmethyl (Guthion®) insecticide supported more bollworms, Heliothis zea (Boddie), and tobacco budworms, H. virescens (F.), than untreated check fields. Larval populations in Kent County fields treated with malathion were considerably greater than in untreated check fields. But in Dickens County, larval populations in fields treated with malathion were about equal to those in fields treated with azinphosmethyl. In late September and early and mid-October when Heliothis populations were greater, fields treated with azinphosmethyl and malathion in an experiment in Stonewall County averaged 2,200 or more Heliothis larvae per acre on at least one inspection date. This compared to an estimated

maximum of 704 larvae per acre in untreated check fields. During the study, the incidence of the tobacco budworm was greater in the Heliothis population in Stonewall County (66 percent) than in either Kent (36 percent) or Dickens County (26 percent) where the bollworm was the dominant species.

73. ; Reeves, R. E.; Almand, L. K.; Hardee, D. D.; and Cross, W. H. 1970. Studies of the boll weevil populations and their movement in the High and Rolling Plains of Texas using male-baited traps, 1968. Tex. Agric. Exp. Stn. Misc. Publ. MP-948, 8 pp.

Traps baited with live male boll weevils, Anthonomus grandis Boheman, as the source of pheromone were evaluated for effectiveness in survey and population studies with boll weevils in 1968 in the High and Rolling Plains of Texas. A trapline along the "Caprock", the escarpment defining the eastern and southeastern limits of the High Plains, was used to determine the number of weevils dispersing from the Rolling Plains to infest High Plains cotton fields and to compare the size of weevil populations above and below the Caprock. Weevils were captured in larger numbers below than above the Caprock where weevils were captured more regularly on traps located near canyons. This indicated that these canyons may serve as important routes for weevils dispersing from the Rolling Plains to infest High Plains cotton fields. Records from traps in counties supporting weevil populations of various sizes were similar to records from actual field infestation counts in comparing the relative abundance of weevils. More weevils were captured on traps near the most heavily infested cotton fields. Traps placed in a cotton field not infested with weevils were effective in detecting incipient infestations of weevils developing late in the season and in studying the seasonal population increase. A total of 3,882 weevils was captured in 8 1/2 weeks in the fall on 16 traps in a heavily wooded area 3.2 miles from the nearest cotton field.

74. , and Rummel, D. R. 1976. Pheromone manipulation of boll weevils entering overwintering habitats. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 62-65.

A study was conducted to determine if the synthetic pheromone, grandlure, could be used to manipulate Anthonomus grandis Boheman into restricted overwintering sites in the fall. Pheromone sites 200 feet square within heavily wooded pastures adjacent to cotton were baited with grandlure from early September to early November when weevil migration was occurring. To determine the effect of grandlure on the dispersion of the overwintering population, leaf litter was sampled for these weevils in October, November, and December. Observations showed that, for 2 out of 3 different pheromone site situations tested, the grandlure baitings affected the distribution of the hibernating population. The weevils were more heavily concentrated in leaf litter in the pheromone-baited sites and the surrounding 200 ft than they were in litter 600 or 1,320 feet, from the pheromone sites.

75. , and Rummel, D. R. 1976. Suppression of boll weevil populations with pheromone traps. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 37-44.

Pheromone traps have proved to be useful and sensitive tools for the research, survey, and monitoring of the boll weevil, Anthonomus grandis Boheman. The employment of pheromone traps has been greatly enhanced by the development of the synthetic boll weevil pheromone, grandlure. Several large experiments have been conducted that have formed the basis for most of the current concepts concerning the use of pheromone traps for weevil suppression. Although much valuable information has emerged from these experiments, the actual value of pheromone traps as a weevil suppression tool is still poorly defined. The validity of the current method used to determine trap efficiency is questionable

and appears to provide unrealistically high suppression estimates. Most researchers are in agreement that if pheromone traps are effective in weevil suppression, they must be employed against low-density populations. However, when traps have been employed in conjunction with other methods, such as reproduction-diapause boll weevil control, to achieve the low-density requirement, the degree of suppression obtained by the separate components has been difficult to determine. The placement of traps within cotton (infield traps) as opposed to placement around the margins of cotton fields does not appear to offer any major improvement in weevil suppression unless the population is extremely small. However, research on the use of the infield trapping system in conjunction with insecticide is currently being conducted, and evaluation of this two component system has not been completed. At present, the employment of pheromone traps for boll weevil suppression cannot be recommended with confidence to Texas producers.

76. , and Rummel, D. R. 1978. Response of Heliothis populations to insecticides applied in an area-wide reproduction diapause boll weevil suppression program. J. Econ. Entomol. 71: 87-92.

Applications of malathion and azinphosmethyl to cotton during the fall to reduce prehibernating populations of Anthonomus grandis Boheman produced an immediate ecological disruption as evidenced by the increase of nontarget pests, Heliothis zea (Boddie) and H. virescens (F.). At peak densities, Heliothis populations were 4-, to 12-fold greater in treated than in untreated fields and commonly reached higher levels in cotton fields treated with azinphosmethyl. However, these populations caused little, if any, economic damage since the Heliothis-feeding damage was confined largely to immature cotton fruits which had little chance of attaining harvest maturity. Further, no carry-over effect of the late-season Heliothis buildup was detected during the subsequent spring and

summer. The late season suppression of prehibernating boll weevils is probably the only insecticidal control method for boll weevils which does not frequently provoke economically damaging outbreaks of nontarget pests such as Heliothis. However, variables such as ecological stability, insecticide type, and timing of treatment will determine the degree of impact the control treatments have on these pests and thus should be considered before this control method is used as a wide scale management tactic.

77. ; Rummel, D. R.; and Adkisson, P. L. 1972. Spread of the boll weevil into the High Plains of Texas. Environ. Entomol. 1: 136-140.

In recent years Anthonomus grandis Boheman has invaded the High Plains, where it currently presents a potential threat to cotton in most of the area. A large-scale insecticidal control program was conducted during each of the years 1964-70 to control the insect. The programs were effective in preventing economic boll weevil damage to cotton in the High Plains. Despite these control efforts, low numbers of the insect advanced many miles west into previously uninfested counties of the High Plains during 1967-69. Distribution of the insect during 1964-70 in the High Plains and adjacent areas of West Texas is presented.

78. ; Wade, L. J.; and Bruce, D. L. 1973. Boll weevils fail to develop resistance to malathion after several years of heavy exposure in the Texas High Plains. J. Econ. Entomol. 66: 791-792.

The dosage-mortality data obtained in 1968 and 1971 with weevils of the control zone and check strains showed similar trends, that is, there was little difference between strains when compared at either the LD_{50} or LD_{90} levels both years. It seemed unusual that the LD_{50} and LD_{90} values determined for both strains were smaller in 1971 than in 1968, but the important point is that there was no evidence that the High Plains strain had developed

resistance to malathion. Although malathion resistance was not detected in the present studies, populations of boll weevils in the High Plains area, as well as in other areas employing reproductive-diapause control procedures, should be checked periodically to detect any changes in susceptibility to the insecticide.

79. ; White, J. R.; Moody, D. S.; and Hardee, D. D. 1972. Overwintering habitats of the boll weevil in the Rolling Plains of Texas. Environ. Entomol. 1: 633-638.

Collections from wing traps baited with male Anthonomus grandis Boheman and from ground trash were used to study overwintering weevil populations in various vegetational habitats in the Rolling Plains of Texas, 1969-71. The primary overwintering habitats were "motts" of sand shinnery oak; communities of woody plants dominated by such species as sand shinnery oak, chinaberry, and poplar; and dense rangeland stands of mesquite. Populations in hibernation varied among specific vegetational sites within the habitats, and hibernating populations were concentrated largely in the proxomity (≤1/2 mile) of cotton fields. Major winter mortality occurred within the hibernating sites during late January or early February.

80. Boyd, F. J. Jr. 1976. Boll weevil population levels during the in-season and reproduction-diapause control phases of the Pilot Boll Weevil Eradication Experiment. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conf., February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 75-81.

There appears to be a definite relationship between the incidence of infested fields and number of boll weevils captured in pheromone traps in the different areas of the eradication zone in 1973. There was an increase in native weevils captured and infested fields as one moved from south to north, with

at least 90% of the trapped weevils coming from the units in which the infestations occurred. This incidence of captured weevils and infestations was directly related to the distance from considerable boll weevil infested cotton acreage outside the experimental area. The apparent relationship between these factors and results of a migration study by Cross indicated that boll weevil migration into the eradication zone did occur. Closely considering all possibilities, and given the fact that the 33 fields found infested, comprising 9.0% of the total acreage, were located in the northern one-third of the eradication zone, it is surmised that the majority of the infestations found in 1973 were caused by migrant, gravid females.

81. . 1976. Operational plan and execution of the Pilot Boll Weevil Eradication Experiment. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conf., February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 62-69.

The eradication plan developed for use in the PBWEE involved the integrated use of several suppression techniques, which included the use of chemical, biological, and cultural control methods. The suppression techniques were executed intensively in the eradication and first buffer zones. In the second and third buffer zones, they were executed less intensively, since these areas were designed to lessen the likelihood of boll weevil migration into the eradication zone. The eradication scheme utilized eight techniques which were designed to progressively reduce the boll weevil population to achieve elimination. These techniques were (1) in-season control, (2) reproduction-diapause control, (3) cultural control - defoliation, (4) cultural control - stalk destruction, (5) pheromone traps, (6) trap crops, (7) pinhead square treatment, and (8) sterile-male releases.

82. , and Brazzel, J. R. 1973. Ultra-low-volume insecticide trails for diapause boll weevil control. J. Econ. Entomol. 66: 498-500.

Trials with insecticides applied at ultra-low-volume rates were conducted during 1968 and 1969 in Kent County, Texas, and during 1970 in Lawrence County, Mississippi, to evaluate the effectiveness of 9 different insecticides or formulations for diapause Anthonomus grandis Boheman control. Malathion was used as the standard material since it is widely used in reproductive-diapause boll weevil control programs. The differences between boll weevil populations among treatments were not significant in the 1968 and 1970 trials. In the 1969 test, azinphosmethyl ULV and LC applied undiluted reduced adult populations significantly below that of other materials.

83. , and Brazzel, J. R. 1975. Survival of boll weevils in bolls on standing cotton stalks during the winter in southern Mississippi and southeastern Louisiana. J. Ga. Entomol. Soc. 10: 99-105.

Adult boll weevils were found to survive the winter in cotton bolls remaining on undestroyed cotton stalks in southern Mississippi and Washington Parish, Louisiana. Approximately two-thirds of the surviving boll weevils were in firm diapause. The highest survival occurred in the southern portion of the study area and generally decreased northward.

84. ; Brazzel, J. R.; Helms, W. F.; Moritz, R. J.; and Edwards, R. R. 1973. Spring destruction of overwintered boll weevils in west Texas with wing traps. J. Econ. Entomol. 66: 507-510.

A large-scale trapping experiment was conducted on 75,000 acres of cotton in the rolling plains area of west Texas to determine if the wing trap baited with live male Anthonomus grandis Boheman would be effective and feasible for use in large-area boll weevil suppression programs. Wing traps were situated in or near the hibernation quarters around each cotton field in the area. Use of live male

boll weevils as the trap lure was considered to be impractical when compared with the use of a synthetic lure, but still feasible for use in a large-scale suppression program. The peak emergence period of emerging overwintered boll weevils, as determined by trap data, occurred from late May to late June. Trap data indicated that boll weevil hibernation was rather localized in the best hibernation sites available around or near any particular field. The number of cotton fields found infested with boll weevils prior to September showed that the wing traps were effective in capturing emerging overwintered weevils. Attempts at growing aldicarb-treated trap rows of cotton were impractical under the climatic conditions of west Texas and therefore were abandoned.

85. ; Edwards, R. R.; Helms, W. F.; and Brazzel, J. R. 1973. Large-scale field trial using a combination of aldicarb and wing traps to suppress boll weevil populations. J. Econ. Entomol. 66: 492-496.

A large-scale field trial was conducted in the rolling plains of west Texas to evaluate the effectiveness and operational feasibility of using 10% aldicarb granules incorporated with trapping, for suppression of overwintered Anthonomus grandis Boheman. It was determined that the treatment of a large area with aldicarb was feasible from an operational standpoint. Cotton field having traps and receiving an infurrow application of aldicarb (1 lb/acre) had average reductions of 90.6% in percent punctured squares and 77.3% in adult boll weevils. The infurrow + sidedres treatment of aldicarb gave a higher degree of boll weevil suppression but resulted in a heavier infestation of bollworms, Heliothis spp. Boll weevil wing traps were noneffective around cotton fields receiving an infurrow application of aldicarb then around untreated field. No increase in trap effectiveness was obtained by addition of a sidedress treatment.

86. Bradley, J. R., Jr.; Clower, D. F.; and Graves, J. B. 1968. Field studies of sex attraction in the boll weevil. J. Econ. Entomol. 61: 1457-1458.

Data from this study indicated that male boll weevils do emit an attractant or assembling scent to which both sexes of its species respond under certain conditions in the field. However, it is apparent from the small number of weevils trapped that response was not spectacular and conclusions cannot be formulated. Response might have been greater had additional weevils been caged in traps, as Hardee et al. reported significantly greater response in laboratory studies to groups of 5, 10, and 25 ♂.

87. , and Phillips, J. R. 1978. Biology and population dynamics. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 15-22.

The geographic range, host range, seasonal life history, diapause and population dynamics of the boll weevil are presented. The ultimate goal from the view of the entomologist, is accuracy in the prediction of insect numbers and damage to cotton through integration of models of major cotton insect pests and cotton production models.

88. Brasher, C.; Mullins, J. A.; and Bennett, S. E. 1971. Electrostatic ULV spraying for control of the boll weevil. J. Econ. Entomol. 64: 1537-1541.

The ULV spraying method was used in combination with charging electrostatic spray particles in malathion for controlling Anthonomus grandis Boheman. Bioassay methods were used in evaluation of application method and rates when applied on cotton with both caged and live weevils attached to small picks (weevilpicks) mounted on cotton plants. By using electrically charged particles and auxiliary air, incorporated with ULV sprays system, about 90% control of boll weevil was acheived with 1.25 lb of malathion per acre, almost equal effectiveness of control was achieved at one-half of the rate applied with the system. Removal of the electrostatic charging component of the system reduced weevil mortality by

5 to 10%. However, removal of the auxiliary air-propelled spray component of the system reduced its effectiveness by about 20%. This reduction was attributed to the increased penetration of the insecticide into the plant canopy by use of the auxiliary air.

89. Brazzel, J. R. 1969. Environmental control measures used in plant pest control programs. In Proceed. of Tall Timbers Conf. on Environ. Pest Con. Meas. 1968 Published by Tall Timbers Res. Sta., Tallahasee, Fla., 1973, pp. 29-35.

The pink bollworm program in the southwestern United States is an example of control by environmental management which has been practiced for many years. This cotton pest diapauses in the larval stage in seed-cotton left in the field at harvest. Cotton is the major host plant and populations which survive the winter on other hosts are negligible. Therefore, successful winter survival is dependent to a great extent upon cultural practices in the field during the off-season. Several agronomic practices have been adopted which adversely affect the survival of the diapause larvae. These have the added benefit of also being good farming practices. Immediately after harvest, stalks and debris are shredded with a mechanical shredder which destroys the food supply and may physically destroy up to 90 percent of the diapause larvae. In the more southerly regions, the date for this host plant destruction is set before the end of the normal growing season, thereby shortening the breeding period during a growing season. This may prevent as much as one or more generations in the fall when a large percentage of the population may diapause. The boll weevil has been the major pest of cotton for approximately 75 years in the southern cotton growing areas. Prior to the widespread use of the synthetic insecticides in the 1940's, control was based primarily upon cultural practices. These control measures consisted of (1) early planting of early maturing varieties, designed to produce as much cotton as possible before

increasing boll weevil populations terminated production, and (2) cultural practices in the fall designed to reduce the overwintering population. Cultural practices included destruction of stalks and food supply as soon after harvest as possible. This was usually accomplished by cutting and burning or by grazing by livestock. In many parts of the country it was a common practice to burn hedgerows and woodland near cotton fields to destroy hibernating weevils. This burning practice was severely curtailed in the 1940's. These practices gave some relief from this pest but never worked very well. Then the discovery of the effectiveness of the new insecticides opened a new era in cotton production in the infested areas. These chemicals gave good control during the growing season and resulted in an extended growing season with yield increases of 100 percent or more.

90. . 1976. A plan for boll weevil elimination in the Cotton Belt. In Boll Weevil, Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974. Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 154-158.

A general plan is presented. It is emphasized that if a national program is undertaken it will be necessary to develop a much more detailed plan of action, along with an environmental impact statement. It is estimated that completion of such a program would require 6 to 10 years and would cost $655 million, based upon 1972 cotton acreage. This cost estimate includes a 20% contingency fund. Finally, there are certain conditions which are essential to the success of such a huge and difficult undertaking: (1) There must be overwhelming support of the program by growers, the cotton industry, and the agencies responsible for program execution. (2) There must be 100% grower participation. (3) We must have the legislative authority to carry out the regulatory requirements and the willingness to exercise that authority. (4)

The growers must be willing to contribute up to 50% of the cost of the program. (5) We must further refine out technology and improve efficiency in execution. (6) We must develop well trained, highly motivated personnel capable of giving the attention to detail necessary for successful execution of the program elements.

91. Brito, L. M. 1975. Integrated control of cotton pests in El Salvador. Folia Entomol. Mex. 33: 24-25. Published in Spanish.

Integrated control of cotton pests in El Salvador uses legal, cultural, biological, mechanical, selective and nonselective chemical components in a control system.

92. Broome, J. R.; Callaham, M. F.; Poe, W. E.; and Heitz, J. R. 1976. Biochemical changes in the boll weevil induced by rose bengal in the absence of light. Chem. Biol. Interactions 14: 203-206.

Rose bengal was shown to be capable of inducing mortality in the boll weevil in the absence of light. The LT_{50} value of 9.3 days calculated for newly emerged adult boll weevils agrees remarkably well with the value of 8.4 days determined for adult worker imported fire ants. The laboratory reared boll weevils are better suited to a study of the associative biochemical changes that take place during the dark incubation with dye since the age of the insects is known and uniform.

93. Bruer, H. L. 1976. Regulatory aspects of boll weevil eradication in the Cotton Belt. In Boll Weevil Suppression, Management and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 159-160.

The technical committee for determining an overall plan for a program to eliminate the cotton boll weevil from the United States divided its work among subcommittees, one of which was that concerned primarily with regulatory

aspects. The committee discussed these requirements as fully as possible in the overall plan, which was published on December 4, 1973. Jim Brown, the committee chairman, listed the regulatory requirements as the six C's: clearance, course of action, cooperation, coordination, cost allocation, and compliance. There should be no difficulty in interpreting these terms. "Clearance" simply entails authority for the effort to eliminate the boll weevil. "Course of action" has to do with the technical plans for such action, including the establishment and administration of elimination zones. "Cooperation" in this context takes on a rather special meaning in that it requires 100% participation. E. F. Knipling phrases it as "full cooperation of all cotton producers." "Coordination" entails such steps in an overall program as a reporting system for cotton acreage, destruction of small isolated plantings, and other items of a similar nature. "Cost allocations" is fully covered in Section 611 of Public Law 93-86 enacted on August 10, 1973. This law will be discussed in more detail later. "Compliance" in the present context comprises such terms as right of entry, quarantines, or other regulations governing movements through eradication zones, disposition of noncommercial cotton, and similar problems.

94. Buford, W. T.; Jenkins, J. N.; and Maxwell, F. G. 1967. A laboratory technique to evaluate boll weevil oviposition preference among cotton lines. Crop Sci. 7: 579-581.

A technique was developed to evaluate a large number of cotton lines in a minimum of time as oviposition sites for the boll weevil. Mississippi field weevils and the A & M laboratory strain were tested for a comparison of their response to various cotton lines. We concluded that: (1) Evaluating cotton lines with the laboratory strain of weevils would closely approximate the cotton varietal differences evident in evaluating with field weevils; (2) Boll weevil oviposition was an insect biological response which could be modified by the host

plant genotype; and (3) 'Triple Hallmark Sea Island,' 'Seaberry Sea Island,' their F_1 hybrid, 'Brown Egyptian', and Seaberry Sea Island X Brown Egyptian were less preferred for oviposition by the boll weevil than 'Deltapine Smooth Leaf.'

95. ; Jenkins, J. N. and Maxwell, F. G. 1968. A boll weevil oviposition suppression factor on cotton. Crop Sci. 8: 647-649.

The rate of boll weevil, Anthonomus grandis Boheman, oviposition was tested on 252 cotton lines, Gossypium hirsutum L., and G. barbadense L., in a nonreplicated mass screening procedure. Boll weevil oviposition was reduced in 26 lines. Replicated tests were performed on six of these by using the A & M laboratory strain and a Mississippi field strain of weevils. The two strains ranked the six cotton lines in relatively the same order. We obtained F_1 hybrids of each of the 26 lines by crossing them with 'Deltapine Smooth Leaf' (DPSL) and tested the hybrids for oviposition with the A & M strain in replicated tests. Significant differences were found. Oviposition values ranged from 49 to 178% of the commercial DPSL parental line. 'S. I. Seaberry' produced the lowest oviposition rate. Inheritance studies with S. I. Seaberry X DPSL were conducted in the F_1, F_2, and backcross progeny. Difficulty was experienced in testing individual F_2 backcross plants since the test required many squares. We did, however, determine that the ability of S. I. Seaberry to suppress boll weevil oviposition was under genetic control.

96. Bull, D. L. 1968. Metabolism of 0,0-dimethyl phosphorodithioate S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one (Geigy GS-13005) in plants and animals. J. Agric. Food Chem. 16: 610-616.

Relatively small amounts of Geigy GS-13005-[0,0-dimethyl phosphorodithioate S-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3.4-thiadiazolin-5-one] were absorbed by cotton plants after foliar, seed, or stem treatments. Only

small concentrations of GS-13005 were translocated to new plant growth and none was detected in the fruit. The highly toxic oxygen analog of GS-13005 was found in extracts of treated plants and insects but not detected in the urine of white rats.

97. . 1968. Metabolism of UC-21149 (2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime) in cotton plants and soil in the field. J. Econ. Entomol. 61: 1598-1602.

Metabolism of S^{35}-labeled UC-21149 (2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl)oxime) in cotton plants and its fate in soil under normal field conditions was investigated. After 2 days the compound was completely metabolized in individually treated leaves, primarily to the toxic sulfoxide derivative 2-methyl-2-(methylsulfinyl) propionaldehyde O-(methylcarbamoyl) oxime. Once formed, the sulfoxide was relatively stable; the biological half-life was about 1 week and 14% of the applied dose was still in this form after 32 days. Studies of translocation demonstrated that there was little movement of radioactivity from treated leaves to untreated areas of the cotton plants. UC-21149 and at least 10 of its derivatives were detected in treated soil. Of these, the sulfoxide was usually the dominant product; UC-21149 was essentially depleted after 1 week. After 8 weeks, 86.3% of the applied radioactivity was lost from the treated soil, either by volatilization or by movement as a result of moisture from rainfall and irrigation.

98. . 1976. Formulations of grandlure. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 1-9.

Grandlure, the synthetic pheromone of the boll weevil, Anthonomus grandis Boheman, is a mixture of four highly volatile chemicals. Both sexes respond to the attractant, and there is evidence that it may function either as an aggregation of sex pheromone. The Environmental Protection Agency has issued

a temporary permit that allows the Animal and Plant Health Inspection Service to use it in survey operations.

99. . 1979. Fate and efficacy of acephate after application to plants and insects. J. Agric. Food Chem. 27: 268-272.

A single foliar application of ^{14}C-labeled acephate was absorbed rapidly by cotton leaves (>50% in 24 h), and unabsorbed residues were essentially depleted in 48 h. The absorbed acephate was metabolized by the leaves to small amounts (ca. 9% of dose) of the insecticide methamidophos and to lesser amounts (<5% combined) of at least four other products. Two of the latter four products were tentatively identified as O-S-dimethyl phosphorothioate and S-methyl acetylphosphoramidothioate. Absorbed acephate and/or its metabolites were rapidly translocated throughout the plant including the fruit. However, with normal application methods, any such translocation of toxicants that might occur is apparently insufficient to kill pests that feed on new growth or fruit. Acephate was considerably more toxic to third-stage tobacco budworms, Heliothis virescens (F.), than to adult boll weevils, Anthonomus grandis Boheman, in tests with topical applications to the insects and with bioassays of treated cotton foliage. Some evidence obtained in studies of the absorption and metabolism of ^{14}C-labeled acephate by the two species suggests that the metabolic conversion of the chemical to methamidophos in tobacco budworms may contribute to the observed differences in susceptibility between species.

100. . 1980. Fate and efficacy of sulprofos against certain insects associated with cotton. J. Econ. Entomol. 73: 262-264.

Topical applications of sulprofos were ca. equally toxic to 3rd-stage larvae from organophosphorus insecticide susceptible (S) and resistant (R) strains (LD_{50} 0.34 and 0.38 μg/insect, respectively) of the tobacco budworm, Heliothis

virescens (F.), and to larvae of S strain (LD_{50} 0.24) of the bollworm, H. zea (Boddie). The chemical was highly toxic (LD_{50} 0.13) to adult lady beetles, Hippodamia convergens Guerin-Meneville, but relatively inactive (LD_{50} 2.4) against the boll weevil, Anthonomus grandis grandis Boheman. Studies with topically applied ^{14}C-labeled sulprofos suggested that these differences in toxicity were related to the rates at which the chemical was absorbed by the insects. In the greenhouse, foliar applications of sulprofos on potted cotton plants were generally more effective against 3rd-stage (S) tobacco budworm larvae than against adult boll weevils. Field tests of sulprofos (0.56, 1.12 kg/ha) against natural populations of Heliothis spp. in cotton demonstrated that control was ca. equivalent to that obtained with the synthetic pyrethroids permethrin (0.11, 0.22 kg/ha) and fenvalerate (0.11 kg/ha) or a standard insecticide mixture of toxaphene, methyl parathion, and chlordimeform (0.86 + 1.68 + 0.14 kg/ha).

101. . 1980. Fate of diflubenzuron after application to cotton and the boll weevil. Southwest. Entomol. Suppl. 1: 2-7.

Very little diflubenzuron is absorbed by the leaves of cotton plants treated by foliar application. This compound adheres well to foliage and is highly resistant to photodegradation on foliar surfaces and to metabolism within leaves. However, this unusual persistance of diflubenzuron on cotton does not result in the accumulation of significant residues in seeds. The chemical is somewhat stable in the soil as long as it is associated with plant litter and it does not leach appreciably. Diflubenzuron is active against female boll weevils exposed by either ingestion or contact. It inhibits the hatch of eggs of exposed females if sufficient concentrations are secreted into the eggs. As time after exposure is extended, treated females recover fertility, and retreatment is required to maintain a significant suppression of egg hatch.

102. , and Borkovec, A. K. 1973. Metabolism of carbon-14-labeled hempa by adult boll weevils. Arch. Environ. Contam. Toxicol. 1: 148-158.

When uniformly carbon-14-labeled hempa, alone or in combination with busulfan, is ingested by the adult boll weevil (Anthonomus grandis Boheman) during a six-day feeding period, hempa is metabolized rapidly and excreted with its decomposition products. The primary metabolic pathway involves the sequential N-demethylation of hempa to the inactive penta-, tetra- and trimethyl derivatives. Radiocarbon liberated during metabolism is expired as $^{14}CO_2$ or is incorporated into natural constituents. Of the radioactive products that are present in adult boll weevils immediately upon transfer from the hempa-containing diet, only 0.6 μg each is in the form of hempa; after 24 hours of feeding on untreated diet, this is reduced to 0.06 μg. In view of the known low acute-and chronic toxicity of hempa to mammals and its low mutagenicity in mammalian systems, it is concluded that the proposed release of 100 chemosterilized weevils per acre would produce only negligible potential environmental contamination and that possible risks could be further reduced by releasing the insects 24 hours or more after treatment.

103. ; Coppedge, J. R.; Hardee, D. D.; Rummel, D. R.; McKibben, G. H.; and House, V. S. 1973. Formulations for controlling the release of synthetic pheromone (grandlure) of the boll weevil. 3. Laboratory and field evaluations of three slow-release preparations. Environ. Entomol. 2: 905-909.

Three slow-release preparations of grandlure, the synthetic pheromone of Anthonomus grandis Boheman, were evaluated in the field at 3 locations in Texas and Mississippi, to compare their relative attractancy to adult weevils during the priod of fall dispersal. All 3 formulations, at both low (3 mg per unit) and high (12 mg per unit) doses of grandlure, were more attractive throughout 14-day test periods than were caged males or

fast-release formulations that were both replaced at 2-day intervals. The combined results of field tests at all locations, and of laboratory analyses of weathered samples, suggested that a physical-barrier system might yield more consistent results, but no single formulation was decidedly superior to the others. Tests demonstrated also that slow-release formulations could be used effectively in the different types of boll weevil traps currently in use.

104. ; Coppedge, J. R.; Ridgway, R. L.; Hardee, D. D.; and Graves, T. M. 1973. Formulations for controlling the release of synthetic pheromone (grandlure) of the boll weevil. 1. Analytical studies. Environ. Entomol. 2: 829-835.

Several different formulations of the synthetic pheromone (grandlure) of Anthonomus grandis Boheman were prepared and tested in the laboratory and field in an attempt to prolong effectiveness of attractant in traps. Of those tested, two extended the effective trap life of attractant for periods greater than one week: (1) a physical-barrier preparation that consisted of a cigarette filter impregnated with grandlure in a solution of polyethylene glycol 1000 (20.4 percent), glycerol (32.3 percent), water (12.8 percent), and methanol (34.5 percent), and contained in an open one-dram galss vial; and (2) a commercial gel formulation. Plastic preparations tested did not improve significantly on the grandlure formulations.

105. ; House, V. S.; Ables, J. R.; and Morrison, R. K. 1979. Selective methods for managing insect pests of cotton. J. Econ. Entomol. 72: 841-846.

In replicated tests in small field plots of cotton, applications of a commercial formulation of Bacillus thuringiensis Berliner (BT) (1121 g/ha) did not adequately suppress heavy populations of Heliothis spp. larvae. When chlordimeform (140 g/ha) was applied in conjunction with this same dose, the level of control increased but did not exceed that provided by chlordimeform alone. Direct com-

parisons of the efficacy of the BT formulations (561 g/ha) and a commercial formulation of Baculovirus heliothis (BH) (148 g/ha) against moderate populations of larvae. When the BH formulation (148 g/ha) or the BT formulation (560 g/ha) was applied in conjunction with releases of Trichogramma (110,000/ha) in test plots oversprayed with diflubenzuron (70 g + 4.7 liter crop oil/ha) to control boll weevils, Anthonomus grandis grandis Boheman, the 2 microbial pesticides caused a similar and significant reduction (compared with the check) in the numbers of both small and large Heliothis spp. larvae. Numbers of undamaged bolls were also significantly greater in microbial-treated plots.

106. , and Lindquist, D. A. 1966. The effects of chronic doses of an organophosphorus inhibitor on cholinesterase activity in boll weevils. Experiments 21: 262-263.

Though absolute proof has not been established, the consensus of most workers is that cholinesterase (ChE) inhibition is the primary biochemical lesion leading to the death of insects poisoned by organophosphorus (OP) insecticides[1,2]. Effects of OP poisoning on mammalian ChE have been reported in some detail, but information on chronic effects in insects is limited. As part of a general investigation of systemic, OP insecticides in cotton plants, we examined changes in the ChE activity of adult boll weevils (Anthonomus grandis Boheman) that received sustained doses of Bidrin (3-hydroxy-N, N-dimethyl-cis-crotonamide dimethyl phosphate) in their diet.

107. , and Lindquist, D. A. 1966. Insect metabolism: metabolism of 3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate (Azodrin) by insects and rats. J. Agric. Food Chem. 14: 105-109.

Oxidative conversion of Azodrin (3-dydroxy-N-methyl-cis-crotonamide dimethyl phosphate) to its N-methylol derivative occurred in five species of insects, boll weevil (Anthonomus grandis Boheman), housefly (Musca domestica Linnaeus),

American cockroach (Periplenata americana (Linnaeus)), bollworm (Heliothis zea (Boddie)), and tobacco budworm (Heliothis virescens (Fabricius)) and white rats. However, formation of the toxic unsubstituted amide derivative of Azodrin by complete oxidative N-demethylation apparently was a minor reaction. Similar metabolites of Azodrin were formed in the different test animals, but at widely different rates.

108. , and Lindquist, D. A. 1968. Cholinesterase in boll weevils, Anthonomus grandis Boheman. I. Distribution and some properties of the crude enzyme. Comp. Biochem. Physiol. 25: 639-649.

1. Homogenates of adult boll weevil, Anthonomus grandis Boheman, apparently contained only one enzyme that catalyzed hydrolysis of choline esters. 2. The enzyme was primarily associated with the particulate fraction of homogenates and was almost evenly distrbuted between the abdomen (55 percent) and the head plus thorax (45 percent). 3. Based on information obtained from studies of substrate specificity, esterine inhibition, and influence of substrate concentration, pH and temperature on activity, the enzyme was tentatively classified as an acetylcholinesterase (AChE). 4. In adult weevils of a colony reared in continuous light, the levels of AChE were relatively constant during a 24-hr period; however, when the weevils were reared with a 14L-10D daily photoperiodic regimen, enzyme activity definitely was higher in weevils during the light hours.

109. ; Lindquist, D. A.; and Coppedge, J. R. 1967. Metabolism of 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime (Temik, UC-21149) in insects. J. Agric. Food Chem. 15: 610-616.

The fate of radiolabeled 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl) oxime (Temik, UC-21149) in insects was examined. Topically applied Temik was absorbed rapidly by adult boll weevils, Anthonomus grandis Boheman, but very

slowly by third instar tobacco budworms, Heliothis virescens (F.). Oxidation at the sulfur atom was the predominant reaction in both species of insects, yielding primarily the sulfoxide derivative of Temik and to a lesser extent the sulfone. Traces of N-demethyl derivatives in excreta of the tobacco budworm indicated some oxidation at the N-methyl position. The principal products of hydrolysis were the sulfoxide and sulfone derivatives of 2-methyl-2-(methylthio) proprionaldehyde oxime.

110. ; Lindquist, D. A.; and Grabbe, R. R. 1967. Comparative fate of the geometric isomers of phosphamidon in plants and animals. J. Econ. Entomol. 60: 341-352.

The fates of the cis and trans isomers of phosphamidon in plants and animals were determined by using radiometric and other procedures. The biological half-lives of toxic forms of the 2 isomers were very short in plants and animals and of comparable duration. Although both isomers were converted to similar oxidative and hydrolytic metabolites, the rates of formation were somewhat different; the faster rate of oxidative N-dealkylation of cis phosphamidon in all biological systems was particularly apparent. Not only were the trans isomers of phosphamidon and its N-deethyl derivative substantially more toxic to adult boll weevils Anthonomus grandis Boheman, and house flies, Musca domestica L., than were the cis isomers, but they also were significantly more potent inhibitors of acetylcholinesterase in the insects. Combinations of sesamex with cis and trans phosphamidon and N-deethyl derivatives caused a substantial increase in the toxicity of all compounds to boll weevils, particularly the cis isomers.

111. ; Stokes, R. A.; Hardee, D. D.; and Gueldner, R. C. 1971. Gas chromatographic determination of the components of the synthetic boll weevil sex pheromone (grandlure). J. Agric. Food Chem. 19: 202-203.

A gas chromatographic procedure was developed by which the four monoterpene components in a synthetic preparation of the sex pheromone of the boll weevil (Anthonomus grandis Boheman) could be analyzed with a single injection. The compounds were detected by hydrogen flame ionization after chromatography on a column loaded with 10% fluorosilicone (QF-1).

112. Bumgarner, J. E., and Lambremont, E. N. 1966. The lipid-class spectrum and fatty-acid content of the boll weevil egg. Comp. Biochem. Physiol. 18: 975-981.

1. Lipids from eggs of the boll weevil (Anthonomus grandis Boheman; Coleoptera, Curculionidae) were fractionated into individual classes by a combination of silicic acid and Florisil column chromatography. Triglycerides were the predominant fraction, and accounted for more than 70 percent of the neutral lipid matter. 2. The fatty acid content of adult males and females and eggs resembles that of the diet when dietary fat content is high. Females feeding on low fat diets deposit lipids in the egg yolk which contain principally thost fatty acids that the adult can synthesize from non-lipid components.

113. Burke, H. R. 1966. Elytral interval polymorphism in Anthonomus grandis Boheman and Anthonomus vestitus Boheman (Coleoptera: Curculionidae). Coleopt. Bull. 20: 104-106.

The account of elytral interval polymorphism in A. grandis and A. vestitus is preliminary. The objectives here were to show that such polymorphism exists and to point out the correlation between incidence of these polymorph variants and geographic areas. Elytral interval polymorphism is presently being used by the author as an additional factor in evaluating geographic variation in the two species and may be of some value in future studies on their genetics. Information derived from field and laboratory studies is now needed as a basis for attempting to determine the nature and significance of the phenomenon.

114. . 1968. Geographic variations and taxonomy of Anthonomus grandis Boheman. Tex. Agric. Exp. Stn. Dep. Entomol. Tech. Rep. 152 pp. (Mimeogr.).

This study was designed to investigate and analyze geographic variation of characters of Anthonomus grandis Boheman in an attempt to determine taxonomic relationships of various populations of the species. This variation is correlated where possible with hosts, biological and morphological differences, and other factors which might shed light on the taxonomy of the species. Ten geographically variable characters were measured in samples from throughout the range of the species. The variation of each of these characters is discussed separately, and all then are treated together in an effort to determine overall patterns of variation. Clinal variation is evident in the cases of a few characters; this variation is in the form of fairly smooth south-north clines along the west coast of Mexico, or stepped clines as in Arizona and along the Texas-Mexico boundary. Several characters vary more or less concordantly in these areas.

115. . 1976. Bionomics of the anthonomine weevils. Annu. Rev. Entomol. 21: 283-303.

The world fauna of the curculionid anthonomine consists of approximately 33 genera and 467 species. As with most weevil groups, the anthonomines are generally poorly known, especially regarding life cycles, host relationships, immature stages and other life processes. Except for a few economic species such as the boll weevil (Anthonomus grandis), the apple blossom weevil (Anthonomus pomourm), and some pests of lesser importance, there is a great paucity of almost any kind of information on these weevils. As a contribution to the knowledge of the biology of the curculionidea, the author and coworkers in recent years have attempted to accumulate more biological data on a wider

range of species within the subfamily. It is mainly results of these studies and the more recent publications of others that serve as a basis for this review.

116. . 1978. Contributions of J. D. Mitchell to the early knowledge of Texas insects. Melsheimer Entomol. Ser. 24: 27-35.

Mitchell became a collaborator, or agent, with the Bureau of Entomology in 1904 and continued in that capacity for a period of 17 years. The establishment of the U.S.D.A. laboratory at Victoria and his friendship with W. D. Hunter undoubtedly had much to do with Mitchell's subsequent participation in entomological research and made possible his major entomological contributions. The laboratory was moved to Dallas in 1905 but fieldwork was continued at Victoria for many years. Mitchell became associated with several outstanding entomologist who were stationed at the laboratory for varying lengths of time, including Hunter, W. E. Hinds, A. W. Morrill, A. L. Quaintance, W. W. Yothers, and W. D. Pierce. Other entomologist visited Victoria during the period of the greatest research activity on the boll weevil and other cotton pests. It was under these stimulating circumstances that Mitchell's noted observational talents were used to best advantage.

117. . 1979. New species of Mexican and Central American Anthonomus Coleoptera: Curculionidae). Southwest. Entomol. 4: 201-208.

Four new species of the genus Anthonomus are described from Mexico and Costa Rica: A. sallei, A. wissadulae, A. phymosiae, and A. salvini. Information on hosts and developmental sites is included. Some data are also presented on the relationship of A. sallei to seed production of its host, Casearia corymbosa.

118. , and Cate, J. R. 1979. A new species of Mexican Anthonomus related to the boll weevil (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 72: 198-192.

Anthonomus hunteri n. sp. is described from specimens collected in the Mexican states of Campeche, Quintanta Roo, Tabasco, and Yucatan. The species is apparently most closely related to the boll weevil, Anthonomus grandis Boheman, from which it is distinguished by several external characters. The known hosts of A. hunteri include the malvaceous plants Hampea nutricia Fryxell and Hampea trilobata Standley.

119. , and Clark, W. E. 1976. Cienfuegosia drummondii as host of the boll weevil, Anthonomus grandis, in south Texas. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 12-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-171, pp. 12-21.

Because of the scattered nature of the plant, its somewhat erratic fruiting pattern, and the often small number of buds and seed capsules available as developmental sites, it is obvious that large numbers of weevils are not likely to be maintained on Cienfuegosia. We feel that the importance of C. drummondii as an alternate host of the boll weevil in south Texas lies in its ability to support small populations of weevils which could form the nucleus of infestations of cultivated crops.

120. , and Cross, W. H. 1966. A new species of Anthonomus attacking cotton in Colombia, with a review of the taxonomy of Anthonomus vestitus (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 59: 924-931.

Anthonomus bisinuatus, a new species closely resembling A. vestitus Boheman, is described from cultivated cotton in the Cauca Valley of Columbia. Geographic variation of A. vestitus from Peru and Ecuador is discussed and evidence

is presented to show the probable existence of 2 distinct forms of this species. The female type of A. vestitus is redescribed. Male genitalia and the metatibiae of both sexes of the 2 species are illustrated.

121. Burt, E. C.; Lloyd, E. P.; and Smith, D. B. 1968. A flail machine for destroying fallen cotton squares infested with boll weevils. J. Econ. Entomol. 61: 1-3.

During the 1965 growing season, a flail machine was used in 4 cottonfields to destroy fallen cotton squares infested with boll weevils, Anthonomus grandis Boheman. Treatments were begun before 1st-generation boll weevils emerged and were continued each week until the treatments began to damage the mature fruit on the plants. Two fields contained a relatively low overwintered population of weevils (46 weevils per acre), and 2 contained a moderately high overwintered population (82 weevils per acre). Results in the 4 fields were compared with those in 2 fields with an overwintered population of 98 weevils per acre that was treated with insecticide. The test indicated that the boll weevil can be controlled by destroying an average 88.8% of the fallen squares, provided that movement into the fields is negligible. Adult populations in fields treated with the flail machine remained stable throughout the treatment and they were slightly higher than in the fields treated with insecticide. The number of egg-punctured squares per acre was higher in the fields treated with the flail machine, but in only 1 field did the percentage of egg-punctured squares exceed the 10% damage level recommended for beginning the application of insecticide. After flail treatments were terminated, 2 to 4 insecticide treatments were necessary to provide complete crop protection.

122. ; Lloyd, E. P.; and Smith, D. B. 1969. Control of the boll weevil by mechanically destroying fallen infested cotton squares. J. Econ. Entomol. 62: 862-865.

Replicated tests were conducted in 1966 in semi-isolated fields in Carroll County, Mississippi, to control Anthonomus grandis Boheman by mechanically destroying fallen infested cotton squares with a flail-type machine. Control in the flail-treated fields was compared with fields treated with ultra low volume (ULV) applications of azinphosmethyl at 0.125 lb/acre applied at 5-day intervals. Flail treatments were made until the machine damaged mature fruit on the plants. Thereafter, the flail fields were sprayed with ULV applications of azinphosmethyl at 0.125 lb/acre. Results indicated that the boll weevil can be controlled with a flail-type machine by destroying fallen infested squares as long as the machine can be operated in the field. However, when the plants become heavily fruited the machine damages the mature fruit. During the season the flail machine picked up an average of 95.3% of the squares that were on the ground.

123. ; Lloyd, E. P.; Smith, D. B.; McCoy, J. R.; and Ingle, F. C. 1970. Boll weevil control with insecticide applied in sprays with narrow= spectrum droplet sizes. J. Econ. Entomol. 63: 365-370.

Results of tests initiated in 1967 to determine the effect of size of spray droplets on boll weevil control showed that adequate control could be obtained with 0.125 lb per acre of azinphosmethyl applied in ultra-low-volume (ULV) sprays with droplet sizes of 140, 200, or 300 μ at 4- to 5-day intervals. The treatments were as effective as a wide spectrum of droplet sizes applied with a spinning-disc sprayer. Azinphosmethyl applied at 0.0625 lb per acre on a 4- to 5-day schedule in a ULV spray in droplet sizes of 100 and 140 μ was as effective as when it was applied in a wide spectrum of droplet sizes at 0.125 or 0.0625 lb/acre. Sprays with droplet sizes of 200 μ gave marginal control when used to apply azinphosmethyl in a ULV spray at 0.0625 lb/acre on a 4- to 5-day schedule and control with 300 μ droplets under the same conditions was inadequate.

124. , and Smith, D. B. 1974. Effects of droplet sizes on deposition of ULV spray. J. Econ. Entomol. 67: 751-754.

Results of quantitative deposit measurements from field tests in which ULV spray droplet sizes were used as treatments showed that droplets of 140 μm diam or larger are necessary for reasonably good control of spray drift. The acceptability of this droplet size will be determined by its effectiveness in controlling the boll weevil and other target pests.

125. ; Smith, D. B.; and Lloyd, E. P. 1966. Application of ultra low volume pesticides with ground equipment. Proc. 1966 Beltwide Cotton Proc.-Mech. Conf., pp. 22-23.

The results of this experiment allow us to conclude that both the mist blower and the rotary disc may be used satisfactorily to apply ultra-low-volume chemicals with ground equipment. Control of the boll weevil by the two machines was not significantly different. The rotary disc appears to give more uniform coverage across the swath with less drift than the mist blower.

126. ; Smith, D. B.; and Lloyd, E. P. 1966. A rotary disc device for applying ultra-low-volume (undiluted) pesticides with ground equipment. J. Econ. Entomol. 59: 1487-1489.

A rotary disc device was developed for ground applications of ultra-low-volume (ULV) undiluted pesticides. The applicator consists of 2 rotating discs powered by a small electric motor and a metering nozzle. One applicator is used on each row. Experimental application of ULV azinphosmethyl (2 lb per gallon), applied to cotton with this device at 0.25 lb per acre gave boll weevil, Anthonomus grandis Boheman, control equivalent to standard methyl parathion applied as a water-emulsion spray at 0.5 lb per acre. Particle deposition within the plant and across the swath was compared with a mist blower ULV applicator. Both gave

equivalent particle deposition within the plant, but the rotary disc device gave more uniform coverage across the swath.

127. ; Smith, D. B.; and Lloyd, E. P. 1967. Efficiency of a flail-type machine in destroying cotton squares deposited on soils varying in surface moisture and roughness. U.S. Agric. Res. Serv. [Rep.] ARS 42-129, 9 pp.

Results of the tests allow us to draw the following conclusions: (1) The efficiency of the flail machine in picking up fallen squares decreased as the moisture in the surface of the soil or the roughness increased; (2) moisture of soil surface affected efficiency of the machine in picking up fallen squares more than roughness of the surface; (3) the flail-type machine picked up enough of the fallen squares (88.1 percent) and killed enough immature weevils (94.8 percent) to provide satisfactory control of boll weevils. However, groundspeed should be increased to above the 3 m.p.h. used in these tests.

128. Byrd, T. 1969. Ancient weevil discovered in old cotton boll. N.C Agric. Exp. Stn. Res. Farming 27 (winter-spring): 13.

Would you believe a boll weevil - one thousand years old? It's true, say entomologists with the U.S. Department of Agriculture. They are referring to a boll weevil found in some old cotton from Mexico by Dr. S. G. Stephens, a geneticist at N.C. State University. Dr. Stephens was examining cotton fragments that USDA scientists had obtained from an archeological excavation in Oaxaca, Mexico. And, lo and behold, there lay a boll weevil entombed in an empty seed hull. Radioactive carbon 14 dating and the presence of Indian pottery in the same location "firmly date the cotton" from about the year A.D. 900.

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129. Callaham, M. F., Broome, J. R.; Lindig, O. H.; and Heitz, J. R. 1975. Dye-sensitized photooxidation reactions in the boll weevil, Anthonomus grandis. Environ. Entomol. 4: 837-841.

Adult boll weevils, Anthonomus grandis, fed for 4 days from emergence on a dye-impregnated artificial diet before illumination at 3800 $\mu W/cm^2$ fluorescent light for 4 h yielded a dietary LD_{50} value of 9.9×10^{-4} moles/liter and a tissue LD_{50} value of 2.4 x 10-7 moles/g wet weight for rose bengal. The dye-sensitized photooxidation reaction was treated mathematically and 2nd order rate constants of 4.50 liters/mole·min for dietary rose bengal and 2.25×10^4 g/mole·min for tissue rose bengal were calculated.

130. ; Broome, J. R.; Poe, W. E.; and Heitz, J. R. 1977. Time dependence of light-independent biochemical changes in the boll weevil, Anthonomus grandis, caused by dietary rose bengal. Environ. Entomol. 6: 669-673.

Diet containing rose bengal, when fed to newly-emerged adult boll weevils in the absence of light, causes serious biochemical changes in the insect. Body weight, total protein, and certain enzyme levels remain constant in the treated weevils as opposed to increases seen in normal weevils. Total lipids decrease in treated weevils relative to the constant values observed in controls. These data, along with fluctuations in the amino acid pool sizes of treated weevils, suggest that the changes are due to an energy stress in the insect, which can become lethal, acting after the dye is absorbed into the tissues of the insect from the gut.

131. ; Palmertree, C. O.; Broome, J. R.; and Heitz, J. R. 1977. Dye-sensitized photoinactivation of the lactic dehydrogenase and acetylcholinesterase from the boll weevil, Anthonomus grandis. Pestic. Biochem. Physiol. 7: 21-27.

The lactic dehydrogenase and acetylcholinesterase enzymes of the boll weevil, Anthonomus grandis, have been shown to be inactivated by dye-sensitized photo-oxidation mediated by substituted xanthenes. The efficiency of the photo-oxidation reaction was correlated with the degree of halogenation of the dye molecule, the efficiency of the dye in singlet oxygen formation, and the strength of binding to lactic dehydrogenase. Changes in the in vivo levels of these enzymes due to ingestion of rose bengal by adult weevils are not further modified in the presence of light.

132. Camp, H. B., and Arthur, B. W. 1967. Absorption and metabolism of carbaryl by several insect species. J. Econ. Entomol. 60: 803-807.

The absorption and metabolism of C^{14} carbaryl was studied in the house fly, Musca domestica L.; stable fly, Stomoxys calcitrans (L.); boll weevil, Anthonomus grandis Boheman; and rice weevil, Sitophilus oryza (L.). Following topical applications of carbaryl, the percentage of the applied dose absorbed by each species of insect within 24 hours was: stable fly 56.7%, house fly 37.3%, boll weevil 12.2%, and rice weevil 3.3%. Five metabolites, including 1-naphthol, were isolated from insects by Florosil and thin-layer chromatography; 4 metabolites were unidentified. Carbaryl was quite stable in both species of weevils. The major metabolite in the feces of house flies was a highly polar material. There were no qualitative differences in number of metabolites isolated from house flies, boll weevils, and rice weevils, but there were quantitative differences in each metabolite present in the internal extract. The species specificity of carbaryl appeared to be functions of rate of absorption and enzymatic degradation within the particular insect species.

133. Canderday, T. D. 1975. Evaluation of insecticides for cotton insect control in Georgia. J. Ga. Entomol. Soc. 10: 25-32.

Labeled and experimental insecticides, applied conventionally and ULV, were compared for efficacy against the boll weevil, Anthonomus grandis Boheman,

and bollworms, Heliothis spp. on cotton. Experiments were conducted at Griffin and Midville, GA. from 1968-72. Azinphosmethyl + methyl parathion and toxaphene + methyl parathion consistently provided good control of weevils and bollworms. Methyl parathion was effective when the boll weevil was the primary economic species; however, it was less effective than certain combinations when bollworms were present in damaging numbers. Leptophos at 1.0-1.5 AI/acre appeared effective against bollworms. Materials showing particular promise included azinphosmethyl + chlordimeform, methyl parathion + chlordimeform, belt + methyl parathion, and PenCap M.

134. ; Womack, H.; and Jordan, C. R. 1973. Evaluation of a boll weevil diapause control program in Georgia. J. Ga. Entomol. Soc 8: 287-294.

A boll weevil, Anthonomus grandis Boheman, diapause control program was evaluated in Randolph County, Georgia for a three year period, 1969-71. Insecticide treatments used in the program reduced the number of weevils entering hibernation each year, thus reducing weevil populations the following spring. However, these reductions were not adequate to alter significantly the number of insecticide applications needed for economic weevil control. Considering the modest cost and possible benefits, it appears that treatments for diapause control are worthwhile as an integral part of an insect pest management program.

135. Cantu, E., and Wolfenbarger, D. A. 1970. Effectiveness of experimental insecticides for control of the tobacco budworm, boll weevil, fall armyworm and twospotted mite. Tex. Agric. Exp. Stn. Consol. Prog. Rep. 2840-2845, pp. 12-14.

In laboratory tests, experimental insecticides Pennsalt TD-5032, Shell SD-14045 and SD-17250 and Stauffer R-2596 were more toxic to the tobacco budworm than a methyl parathion standard at 0.01-percent concentration.

American Cyanamid E.I. 72016 was more toxic to the fall armyworm than the DDT standard at 0.01 percent. Only American Cyanamid E.I. 72016 gave a higher kill of the boll weevil than an azinphosmethyl standard. Foliar sprays of Geigy GS-13006, Bay 91273 and Bay 93820 were more effective against the two-spotted spider mite than the standard malathion at 0.01 percent. Hercules 18526 was more effective against this mite as a systematic than the standard demeton at 1 part per million. In topical application tests, the highest LD_{50}'s obtained with methyl parathion and Azodrin® on tobacco budworm larvae were 1-fold to 6-fold greater in 1969 than in 1968, respectively.

136. , and Wolfenbarger, D. A. 1970. Toxicity of three pyrethroids to several insect pests of cotton. J. Econ. Entomol. 63: 1373-1374.

Three cyclopropane carboxylate pyrethroids, SBP-1382 (5-benzyl-3-furyl methyl 2, 2-dimethyl-3-(2-methylpropenyl) cyclopropane carboxylate, SBP-1390 (5-benzyl-3-furyl) methyl d-trans-2, 2-dimethyl-3-(2-methylpropenyl) cyclopropane carboxylate, and tetramethrin in foliar sprays were toxic to the southern armyworm. SBP-1382 was the most active against the tobacco budworm. SBP-1382 and SBP-1390 caused equal kill of the fall armyworm and were more effective than tetramethrin. SBP-1382 at 0.25% concentration was not toxic to spider mites and gave 35% kill of boll weevils after 48 hr.

137. , and Wolfenbarger, D. A. 1971. Effectiveness of experimental insecticides against the tobacco budworm, boll weevil, fall armyworm and two-spotted spider mite. Tex. Agric. Exp. Stn. Dept. of Entomol. Tech. Rep. 19, pp. 26-32.

In laboratory tests, experimental insecticides methyl parathion, Shell SD-15568, Sumitomo K-9, Sunitomo S-4084 and Vero Beach Bay 78537 and Bay 88941 were about

equally toxic to the tobacco budworm at 0.05 percent. Cela S-2957, Chevron RE-12420, Chevron RE-13913, Hercules A-16434, Sumitomo K-9, Sumitomo S-4084 and Vero Beach Bay 88941 were equally or more toxic against the fall armyworm than methyl parathion at 0.01 percent sprays. Chevron RE-11776, DuPont 1410, 3M MBR-6168, Monsanto 856, Sumitomo S-4084, Upjohn V-34013 and Mobam were more toxic to the boll weevil than azinphosmethyl at 0.25 percent. Cela K-673, Cela S-2957, Chevron RE-12420, Chevron RE-13913, DuPont 1410, Hercules A-16434, Hercules 18009, Hercules 18010, Sandoz 52092, Sandoz 52097, Sandoz 52114, Sandoz 52117, Sandoz 52118, Stauffer R-16374-B, Stauffer R-15206, Stauffer R-15644, and Vero Beach Bay 88941 were more toxic to the two-spotted spider mite than malathion at 0.01 percent. Hercules 17414, Sandoz 52097, Sandoz 52114, Sandoz 52117 and Stauffer R-16374-B were more toxic as a systemic against this mite than demeton at 1 part per million. In topical application tests, the greatest LD_{50} obtained with methyl parathion against tobacco budworm larvae from a Brownsville, Texas field culture was 16X greater in 1970 than in 1969.

138. , and Wolfenbarger, D. A. 1973. Effectiveness of experimental insecticides against the tobacco budworm, boll weevil, fall armyworm and two-spotted spider mite. Tex. Agric. Exp. Stn. Dep. Entomol. Tech. Rep. 73-20, pp. 26-31.

Sprays (0.05 percent concentration) of methyl parathion, Shell SD-24073, and SD-24905 were about equally toxic to the tobacco budworm. Sprays (0.01 percent of Cela S-2956, Shell SD-24052, SD-24073, SD-24074, SD-24905, and SD-25735 were equally or more toxic to the fall armyworm than an equivalent spray of methyl parathion. Sprays (0.25 percent wt/v) of Cela S-2956 and Mobil MC-3815 were more toxic to boll weevils than an equivalent spray of azinphosmethyl. Sprays (0.01 percent) of Ansul AN-57000 and AN-57003; Cela S-2956; Ciba C-17475; Hercules 16801 and 20656; Mobil MC-3427, MC03470, MC-

3515, MC-3815, and MC-4158; Shell SD-24052 and SD-25735 were more toxic to the two-spotted spider mite than equvalent sprays of malathion. Also, Mobil MC-3815 and Shell SD-24908 (1 ppm) were more toxic as systemics against this mite than demeton. The lowest LD_{50} for methyl parathion against tobacco budworm collected from cotton near Brownsville has decreased steadily since 1970. The highest LD_{50} has been variable from year to year. In 1971, the high and low LD_{50}'s were about equal; there was about a 35X difference in 1972.

139. , and Wolfenbarger, D. A. 1973. New compounds showing selective activity against the tobacco budworm and other lepidopteran species, the boll weevil and the two-spotted spider mite. J. Econ. Entomol. 66: 527-529.

Among the different types of compounds, we found considerable selective activity. The pyrethroids showed the greatest activity against the 3 lepidopteran species; the 2-hydroxy-3-biphenylcarboxanilides showed the greatest activity against the twospotted spider mite, and only MON-0856 was active against the boll weevil.

140. Cargill, R. L., and Wright, B. W. 1975. A new fragmentation reaction and its application to the synthesis of (±)-grandisol. J. Org. Chem. 40: 120-122.

Grandisol (1), a component of the pheromone released by the male boll weevil, Anthonomus grandis Boheman, has been synthesized by a variety of routes. We report here a convenient synthesis of racemic 1 that involves a novel fragmentation of an ozonide.

141. Carter, F. L., and Phillips, J. R. 1973. Diapause in the boll weevil, Anthonomus grandis Boheman, as related to fruiting activity in the cotton plant. Arkansas Acad. Sci. Proc. XXVII: 16-20.

Studies in Arkansas show that boll weevil diapause is related to changes in fruiting activity of the cotton plant. Generally, when larval development

took place while fruiting levels were increasing or being held at a high level, diapause in resulting adults was low (0-20%). Diapause was approximately 20-50% when larval development coincided with decreasing fruiting levels, and was 50-100% as true cut-out approached. Regrowth cotton generally lowered diapause incidence and as fruiting levels decreased, diapause increased. Therefore, the boll weevil not only responds to short photoperiods that are characteristic during the fall in the temperate zone, but also may respond throughout the season to changes in fruiting activity of the cotton plant.

142. , and Phillips, J. R. 1974. Factors influencing seasonal diapause in the boll weevil. Arkansas Farm Res. XXIII (May-June): 2.

The data show that boll weevil diapause is influenced throughout the season by factors associated with changes in the physiological condition of the cotton plant.

143. Casey, J. E.; Lacewell, R. D.; and Sterling, W. 1975. An example of economically feasible opportunities for reducing pesticide use in commercial agriculture. J. Environ. Qual. 4: 60-64.

Due to increasing resistance of the bollworm, Heliothis zea (Boddie), and tobacco budworm, Heliothis virescens (F.), in 1968 and 1969, the Texas Department of Corrections in cooperation with the Texas Agricultural Experiment Station, initiated a new pest management strategy. This new strategy was basically (i) to control boll weevil with a fall diapause program, (ii) control fleahopper with low dosages of insecticides applied as early as feasible and (iii) to terminate fleahopper, Pseudatomoscelis seriatus (Reuter), treatments quickly to allow beneficial insects to build and control bollworm and budworm. Comparing 1968-69 cotton, Gossypium hirsutum L., production (traditional insecticide use declined from 14.51 kg/ha to 7.19 (12.9 to 6.4 lb/acre) while lint yield increased due to the new pest management strategy on the Brazos River region of

the Texas Department of Corrections cotton farms. Estimated net returns would be expected to increase $55.87 ($22.61 on a per acre basis) with adoption of the new pest management strategy compared to the traditional strategy. The Trinity River region of the Texas Department of Corrections cotton farms indicate that the new pest management strategy brought about a 50% reduction in per hectare quantity of insecticides used (from 12.28 to 6.22 kg [10.8 to 5.6 lb]), a 90 kg/ha (80 lb/acre) yield increase, and $85.50/ha ($34.62/acre) net return increase. Expanding these results to the 86.8 thousand hectares (215 thousand acres) to cotton in the surrounding area indicates that the new pest management strategy would increase cotton output by over 27.4 thousand bales, reduce quantity of insecticides applied by 607,000 kg (14. million lb) while increasing producer net returns over 5 million dollars.

144. Cate, J. R.; Curry, G. L.; and Feldman, R. M. 1979. A model for boll weevil ovipositional site selection. Environ. Entomol. 8: 917-921.

A model for the selection of boll weevil oviposition sites by size category is presented. The predictions of the preference model are similar to ten weekly experimental distributions obtained throughout the 1978 growing season. Chi-squared goodness of fit tests support the model predictions; whereas, the nonpreference hypothesis for ovipositional site selection is statistically rejected.

145. , and Skinner, J. L. 1978. Fate and identification of pollen in the alimentary canal of the boll weevil, Anthonomus grandis. Southwest. Entomol. 3: 263-265.

Pollen collected from the gut of boll weevil, Anthonomus grandis Boheman, can be utilized to positively identify food plants of this weevil. Pollen grains are excreted from the gut by 18 hrs after feeding and may be voided by 10 hrs after feeding if the weevil feeds subsequent to a particular

pollen meal. Weevils collected from the field must be preserved in ethanol (75%) to preserve the pollen grains intact in the gut. A technique for extraction and slide mounting of pollen grains is given.

146. Chambers, D. L. 1977. Quality control in mass rearing. Annu. Rev. Entomol. 22: 289-308.

Great progress has been made in recent years in understanding the effectiveness of a massive insect release program. Techniques have been developed to test most of these; routine monitoring is now conducted on some. Protocols exist for assessing quality and continuity of production. Resources need to be applied to understanding and incorporating behavioral requisitic into monitoring protocols that realistically reflect program objectives.

147. Chang, S. C., and Stokes, J. B. 1979. Conjugation: the major metabolic pathway of ^{14}C-diflubenzuron in the boll weevil. J. Econ. Entomol. 72: 15-19.

The metabolic fate of ^{14}C-diflubenzuron was studied after it was injected into Anthonomus grandis grandis Boheman. Four days posttreatment, recovery of ^{14}C was 57.7% from treated weevils and 25% from the excreta. In the weevil, 57.3% of the ^{14}C were recovered as unchanged diflubenzuron while 0.4% was recovered as conjugates. In the excreta, ca. 2% each of diflubenzuron and 2, 6 difluorobenzamide were found and the remainder was conjugates. The total amount of conjugates was ca. 18.7%. Percentages were calculated on the basis of the total injected amount. The conjugates consist of 3 or more compounds, all of which were immediately excreted as very polar compounds. Upon acid hydrolysis, radioactive moieties from the conjugates were identified as N[[(4-chloro-2-hydroxyphenyl)amino] carbonyl]-2, 6-difluorobenzamide and N-[[(4-chlorophenyl) amino]carbonyl]-2, 6-difluoro-3-hydroxybenzamide, plus 2 unknowns.

148. , and Woods, C. W. 1979. Metabolism of ^{14}C-penfluron in the boll weevil. J. Econ. Entomol. 72: 781-784.

The metabolism of ^{14}C-penfluron (2.6-difluoro-N-[[[4-(trifluoromethyl)phenyl]=amino]^{14}C-carbonyl]benzamide) were studied in Anthonomus grandis grandis Boheman. Recoveries of radioactivity of 99 and 94.36% were obtained after 4 days and 1 week, respectively, from weevils that had been injected with 124,970 DPM (4.61 μg/weevil). On the basis of the total injected amount, 97.74% of the label recovered from the extract of weevils 4 days posttreatment were unchanged penfluron and 0.16% was conjugates. Similarly at 1 week posttreatment, 90.56% were unchanged penfluron and 0.2% was conjugates. Less than 1% of additional radioactivity was recovered from weevil residues in both experiments. Four days posttreatment, recovery from excreta extract was 1.02%; 0.33% was unchanged penfluron; 0.06% was 2, 6-difluorobenzamide; and 0.63% was conjugates. Similarly, at 1 week posttreatment the recovery from excreta extract was 3.41%; 1.33% were unchanged penfluron; 0.20% was 2, 6-difluorobenzamide; and 1.87% were conjugates. The conjugates consisted of 2 metabolites which upon acid hydrolysis yielded a single relatively nonpolar metabolite that was assumed to be a hydroxylated derivative of penfluron.

149. Chang, T.-H. and Riemann, J. G. 1967. H^3-thymidine radioautographic study of spermatogenesis in the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 60: 975-979.

The time sequence of spermatogenesis in the boll weevil, Anthonomus grandis Boheman, was studied with H^3-thymidine radioautography. The spermatocytes required 10 days to mature into sperm (from the premeiotic DNA synthetic period). Of these, a little more than 4 days is used to reach prophase I, less than 1 day is spent in meiotic devision, and more than 5 days is spent in spermiogenesis. The cyst cells, some epithelial cells of the vas deferens, and follicle cells were also labeled with thymidine.

150. Chang, Y.-Y. H.; Frazier, J. L.; and Heitz, J. R. 1979. Time course of enzyme development in the boll weevil, Anthonomus grandis. Comp. Biochem. Physiol. 62B: 45-50.

1. The specific activities of lactic dehydrogenase, α-hydroxybutyric dehydrogenase, glutamic oxalacetic transaminase, glutamic pyruvic transaminase, and acid phosphatase were monitored in adult male and female boll weevil homogenates for eleven days post emergence. 2. The above enzymes, plus β-glucuronidase, were monitored in adult male and female boll weevil hemolumph for 10 days post emergence.

151. ; Haynes, J. W.; Frazier, J. L.; and Heitz, J. R. 1979. Differential enzyme activity in normal and sterile boll weevils. Comp. Biochem. Physiol. 62B: 51-56.

1. Whole-body homogenate and hemolymph enzyme profiles of normal and γ-irradiated boll weevils were compared. 2. The specific activity of homogenate lactic dehydrogenase (LDH) in treated males were significantly lower than that in normal males (73 ± 3 vs 104 ± 3mU/mg protein). 3. The specific activity of homogenate acid phosphatase (AP) in treated females was significantly lower than that observed in normal females (89 ± 5 vs 109 ± 5mU/mg protein). 4. Hemolymph LDH and AP showed a comparable activity pattern to homogenate LDH and AP activities. 5. The homogenate LDH activity in normal males correlated well with egg production and egg hatching by females after mating with normal males. 6. Low LDH activity corres; nded with very low egg production and no egg hatching in irradiated males. 7. LDH and AP may be monitored to assess the sterility of the boll weevil after γ-irradiation.

152. Cherry, E. T. 1974. Monitoring boll weevil movement with pheromone traps. Tenn. Farm Home Sci. Prog. Rep. 90: 27-29.

Boll weevil movement in Tennessee was similar to that recorded in studies con-

ducted in other cotton growing areas. Two distinct periods (spring and fall) were observed. The long range movement (10 to 13 miles) in the fall indicated that migration is occurring in Tennessee. Late-season or boll weevil diapause control programs must be designed to allow good isolation (ideally 50+ miles, since the boll weevil has been known to fly 45 miles) from untreated cotton, since the boll weevil is capable of dispersing for great distances.

153. ; Bryan, J. M.; and McCutchen, T. C. 1974. Boll weevil management studies. Tenn. Farm & Home Sci. Prog. Rep. 90: 32-34.

There were no significant yield increases in plots where insecticide applications were begun at the standard 10% boll weevil infestation level compared to the 20, 30, and 35+ percent levels. Therefore the Tennessee cotton grower may be abl to save on his boll weevil control costs by using fewer applications when infestation levels are lower. The data reported here are preliminary and 2 years' additional data under different insect and environmental conditions are needed before valid recommendations can be made. If the same trend exists after this period, the initial infestation level to recommend boll weevil control can be raised.

154. ; Connell, J. M.; and McCutchen, T. 1973. Boll weevil control with frego bract cotton. Tenn. Farm & Home Sci. Prog. Rep. 87: 10-11.

Oviposition suppression was higher in the areas where the overwintered boll weevil populations were lower. Boll weevil populations, using oviposition as an indirect measure of population, were controlled by the resistant character frego without insecticides at Milan and Jackson for the whole season and until late season at Ames. Plant bug damage to frego cotton was evident although the relative numbers present were not significantly higher than on the normal cotton. It was evident that boll weevil populations could be suppressed with a resistant character such as frego. The use of this type

of resistance in the future depends upon the desire of the commercial plant breeders to develop higher yielding varieties containing the frego character. Average yields in pounds of seedcotton per acre of frego cotton used in this test were: Ames, 1405; WTES, 2017; and MFS, 1828.

155. , and Pendergrass, J. E. 1973. The use of pheromone traps for survey of overwintering boll weevil populations in west Tennessee. Tenn. Farm & Home Sci. Prog. Rep. 86: 20-21.

Preliminary results indicate that the boll weevil is capable of overwintering throughout west Tennessee. This study will be continued for 2 more years to evaluate the data under different weather conditions. Proceeding northward in West Tennessee, the cotton acreage becomes scattered and good boll weevil hibernation sites are limited. It now seems that lack of hibernation sites rather than more severe winter temperatures is the main reason for lower boll weevil populations in the northern than in the southern areas of West Tennessee. Cotton growers north of area 1 may never have the annual boll weevil pressures that exist in this area but they should know that the pest survives their winters. Cotton in these areas should be inspected for boll weevil infestations earlier than the normal migration period (mid-August).

156. ; Pendergrass, J. E.; Bryan, J. M.; and Goddard, R. J. 1973. Boll weevil population suppression with late-season insecticide applications. Tenn. Farm & Home Sci. Prog. Rep. 86: 11-13.

Results from the 4 year study at Ames Plantation, Tenn., indicate that spring boll weevil populations can be reduced by applying insecticides late in the previous season. In-season control can be delayed by 2 to 4 weeks the following season. Results are better when the treated cotton acreage is well isolated from untreated cotton. Further research is needed on the summer and fall biology and population dynamics of the boll weevil under Tennessee cotton

growing conditions. With these data, better timed diapause programs could be initiated which could return more dollars to the cotton grower. For the best results, cotton acreage in a diapause control program should be included in a cotton insect scouting program the following growing season.

157. Chesnut, T. L., and Cross, W. H. 1971. Arthropod parasites of the boll weevil, Anthonomus grandis. 2. Comparisons of their importance in the United States over a period of thrity-eight years. Ann. Entomol. Soc. Am. 64: 549-557.

In 1965, a survey was made across the cotton belt from South Carolina through Texas to determine the current status of parasitism of the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae). Samples were taken from 42 cotton fields. Also, results of similar surveys made in 1934, 1935, and 1936 were summarized and compared with those of the 1927, 1930, and 1965 surveys. In 1965, 12.77% of the boll weevils were parasitized compared with 4.05% in 1934. More parasites were found in weevil larvae in hanging squares than in larvae in fallen squares, and parasitism was higher in weevils collected from cotton grown in the hill region than in weevils collected from cotton grown in the coastal plains. Some developing resistance to insecticides in the parasites was suggested by records of heavy parasitism in treated fields. Bracon mellitor Say was much the most important natural parasite and accounted for 74.5% of the parasites recovered in 1965. Aliolus curculionis (Fitch) and Eurytoma gossypii Bugbee ranked second and third, and accounted for 12.3 and 5.3% of the parasites, respectively.

158. Childress, D., and Williams, P. P. 1973. Control of a bacterial contaminant of boll weevil diet. J. Econ. Entomol. 66: 554-555.

In our laboratory, loss of boll weevils, Anthonomus grandis Boheman, from microbial contamination of the diet has been a regular occurrence (1-20%

of larval cultures). Attempts to prevent contamination have included: sterilizing the diet, incorporating the antibiotic tetracycline (Polyotic®, 0.2% final diet concentration), spraying the surface of the diet with a 6% solution of formaldehyde, and partially desiccating the diet after implantation of the eggs. However, these preventive measures have been ineffective in controlling a slime-producing contaminant which is evidently widespread in many types of insect cultures. The purpose of this research was to identify the contaminant and to determine a means of controlling it with minimal amounts of antimicrobial additives.

159. Cleveland, T. C., and Parencia, C. R. 1976. History of the USDA Cotton Insects Research Laboratory, Tallulah, Louisiana, 1909-1973. Bull. Entomol. Soc. Am. 69: 403-407.

On June 30, 1973, after 64 years of continuous operation, the USDA Cotton Insects Research Laboratory, Tallulah, Louisiana, closed. Since the Laboratory began in 1909, many prominent entomologists have been members of the staff. Their pioneering efforts in evaluating and developing chemical insecticides and application techniques for the control of pest insects in cotton are widely recognized. The Laboratory was the acknowledged leader in research on the boll weevil, Anthonomus grandis Boheman, for over half a century and provided an invaluable service to cotton growers when the boll weevil invaded the Mississippi Delta and spread to the East Coast.

160. , and Scott, W. P. 1967. An improved technique for aerial applications of ultra-low-volume materials to experimental plots. J. Econ. Entomol. 60: 1761-1762.

An improved system is described in detail. Some advantages of the new system are: (1) constant pressure is maintained; (2) the spray is turned on and off instantly; (3) calibration is accurate; (4) pump priming is eliminated; (5)

less time is needed to drain and clean the system; (6) less material is required to make the spray system operable; (7) there are fewer operating parts; and (8) the spray system can be calibrated to apply the required dose before the plane is flown.

161. ; Scott, W. P.; Davich, T. B.; and C. R. Parencia, C. R. Jr. 1966. Control of the boll weevil on cotton with ultra-low-volume (undiluted) technical malathion. J. Econ. Entomol. 59: 973-976.

Applications of ultra-low-volume (undiluted) technical malathion at 8, 12, and 16 fluid oz per acre (about 10, 15, and 20 actual oz per acre) from a J-3 Piper Cub flying 15 feet above the cotton in 75-foot swaths were as effective against the boll weevil, Anthonomus grandis Boheman, as the standard application of methyl parathion (0.4 lb per acre in 2 gallons of water applied in 37.5-foot swaths from a plane flying in the conventional manner directly above the cotton). Populations of bollworms, Heliothis zea (Boddie), were not sufficiently large to allow evaluation of the control achieved by the 4 treatments. Numbers of boll weevils found in surface woods trash in the fall and spring near treated fields were reduced considerably by fall applications of technical malathion, compared with areas that received no late treatment. The populations of overwintered weevils found in cotton planted in 1965 in the area treated in the fall of 1964 were also considerably reduced over that found in an area that had received no treatment.

162. Coakley, J. M.; Maxwell, F. G.; and Jenkins, J. N. 1969. Influence of feeding, oviposition, and egg and larval development of the boll weevil on abscission of cotton squares. J. Econ. Entomol. 62: 244-245.

The results obtained with implantation of larvae and with injection of water homogemates of 2nd and 3rd-instar larvae demonstrated that these 2 larval instars caused the reaction in the plant that resulted in abscission of the

squares. The biological assay method employed in this study may be used by plant physiologists in studying the physiological and biochemical changes that occur during the abscission process.

163. Cobb, P. P., and Bass, M. H. 1968. Some effects of photoperiod, temperature, and food on the induction of diapause in the boll weevil. J. Econ. Entomol. 61: 624-625.

Newly emerged adult Anthonomus grandis Boheman collected from squares during mid-June to mid-August, were subjected in groups of 40 to various combinations of food, temperature, and photoperiod. Exposure to each of these factors individually resulted in no evidence of diapause. However, certain combinations did result in diapause in studies where photoperiod, temperature,and food variations were interacted. Generally, the greatest incidence of diapause and fat content occurred in those groups subjected to a 10-hour, 80°F photoperiod, a 14-hour, 50°F dark phase, and fed squares or bolls. Diapause in males seemed to exceed that in females in all groups with a 10-hour photoperiod and a constant 80°F temperature. The occurrence of diapause increased in groups with an 80-50°F temperature combination. Less fat accumulation was observed in groups fed laboratory medium.

164. Coker, R. R. 1976. Economic impact of the boll weevil. In Boll Weevil Suppression, Management and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tenn. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 3-4.

Crop losses and control costs alone range from $200 million to $300 million every year. More insecticides are applied for boll weevil control than for control of any other crop insect. More than $21 million in Federal, State, and cotton industry funds have been spent exclusively for boll weevil research since the BWRL was put into operation in 1961. This is a sizable,

yet very wise investment, in the opinion of many in Government and in the cotton industry. But it will be largely wasted unless the elimination program proceeds. If the boll weevil is allowed to continue its ravages, much of this investment will have gone into a mere holding action.

165. . 1976. Report of Industry Action Committee. In Boll Weevil Suppression, Management and Elimination Technology, Proceedings of a Conference, Feb. 13-15, 1974, Memphis, Tenn. U.S. Agric. Res. Ser. [Rep.] ARS-S-71, pp. 167-168.

Our basic job, of course, assuming a favorable decision by the U.S. Department of Agriculture, is to provide advice and guidance for Cotton Council activities in support of the program at both Washington level and at the state and local levels. In Washington, we plan to work with the Executive Branch on program specifics, and with the Congress on appropriations. In the State-level committees and procedures to help facilitate the program as it progresses. In some cases, State legislation may be needed, and we expect to provide assistance in such circumstances. In short, we want to do everything we can to help get the elimination job done as quickly as possible.

166. Cole, C. L. 1980. Effectiveness of diflubenzuron in the upper Gulf Coast of Texas. Southwest. Entomol. Suppl. 1: 22-26.

Diflubenzuron was compared to azinphosmethyl as a control for overwintered boll weevils. Punctured squares were detected earlier in fields treated with diflubenzuron than in those treated with azinphosmethyl. Dissections of punctured squares showed a reduction in boll weevil survival where 3 to 5 applications of diflubenzuron were applied. In fields treated with 5 applications of diflubenzuron, the retention of punctured squares after 2 wk exceeded 70%.

167. ; Adkisson, P. L.; and Fye, R. E. 1973. Seasonal abundance of Heliothis larvae on cotton in the Presidio, Texas area. J. Econ. Entomol. 66: 524-526.

In 1967, a typical bollworm-tobacco budworm population curve with generation peaks at approximately 30-day intervals was established for the 150 fields in the fall boll weevil control program aimed at killing diapausing boll weevils with azinphosmethyl. The greatest numbers occurred during the 2nd week of October. Producers in the Redford area stopped controls for bollworms when treatment for boll weevils began and populations increased to 22,000 larvae/acre. In Presidio some producers continued to treat for bollworms when treatment for boll weevils began and populations increased to approximately 12,000/acre. In Candaleria, very little insecticide was applied during the growing season but larval populations during the fall spray program never attained the high of 10,000 larvae/acre recorded earlier in the season.

168. Coppedge, J. R.; Bull, D. L.; House, V. S.; Ridgway, R. L.; Bottrell, D. G.; and Cowan, C. B., Jr. 1973. Formulations for controlling the release of synthetic pheromone (grandlure) of the boll weevil. 2. Biological studies. Environ. Entomol. 2: 837-843.

Trapping studies were conducted in a large field cage and in the field as part of a coordinated effort to develop a formulation that would control the release of grandlure, the synthetic pheromone of Anthonomus grandis Boheman. From these and related studies, two new formulations were developed that controlled the release of this pheromone. These formulations were evaluated extensively at several locations and found to be effective for at least two weeks, during which period they were more attractive than either caged male boll weevils or current formuations. Evidence presented showed clearly that attractiveness of any grandlure formulation is influenced by the dose and relative proportions of the four components of the pheromone.

169. ; Lindquist, D. A.; Ridgway, R. L.; Cowan, C. B.; and Bariola, L. A. 1969. Sidedress applications of Union Carbide UC-21149 for control of overwintered boll weevils. J. Econ. Entomol. 62: 558-565.

Union Carbide UC-21149, 2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl)oxime, applied as a sidedressing to 4 to 5-acre plots of cotton provided effective control of Anthonomus grandis Boheman for several weeks. Mortality of released laboratory-reared boll weevils indicated control for 2-4 weeks; the number of punctured squares and adult boll weevils, sampled with a tractor-mounted insect-collecting machine, indicated control for 3-6 weeks. Two applications of 2 lb UC-21149 per acre applied 9-10 days apart were effective for 4-5 weeks, while a single application was effective for 2-4 weeks. More bollworm, Heliothis zea (Boddie), and tobacco budworm, H. virescens (F.), and fewer beneficial insects were found in treated than in the untreated plots.

170. , and Ridgway, R. L. 1973. The integration of selected boll weevil suppression techniques in an eradication experiment. U.S. Dep. Agric. Prod. Res. Rep. 152, 25 pp.

The initial step in demonstrating the feasibility of boll weevil eradication was to critically review the most promising current suppression techniques. Next, several supporting experiments were designed to provide additional information on certain suppression methods. Finally, an experiment was planned specifically to demonstrate the technical feasibility of boll weevil eradication. The supporting experiments included studies of (1) in-furrow applications of aldicarb for boll weevil control, (2) boll weevil trapping systems, and (3) mechanical sampling of boll weevils on fruiting cotton plants. For the specific eradication experiment, the suppression techniques selected were (1) reproduction-diapause control, (2) pheromone wing traps, and (3) in-furrow and side-dress applications of aldicarb. The extensive sampling

that failed to detect any living boll weevils in cotton on the Graves farm until after September 1 and the presence of an infertile female indicated that boll weevil reproduction was prevented until the insects began to move onto the farm from adjacent cotton. Based on calculations of the maximum population of overwintered boll weevils that remained on the farm, the overwintered population can be estimated to have been as low as one boll weevil per 100 acres.

171. ; Stokes, R. A.; Kinzer, R. E.; and Ridgway, R. L. 1974. Biological evaluations of slow release formulations of aldicarb. J. Econ. Entomol. 67: 292-294.

In 2 field-cage tests, a slow release granular formulation consisting of 80% petroleum charcoal, 10% water-insoluble binder, and 10% aldicarb (designated PC-10) applied to the soil gave an additional 7-10 days of control of the boll weevil, Anthonomus grandis Boheman, compared with the standard corncob formulation applied in the same manner. A formulation with 20% water-insoluble binder (designated PC-20), and consequently a slower rate of toxicant release, gave similar results in 1 test, but in a 2nd test was no more effective than the corncob formulation. In 2 of 3 field tests, counts of plant stand indicated that the PC-20 formulation was less damaging to cotton seedlings than the corncob formulation when both were applied as in-furrow treatments at planting. In 3 field tests, the PC-20 formulation appeared more effective against the boll weevil than the corncob formulation. Also, it was more effective against the cotton fleahopper, Pseudatomoscelis seriatus (Reuter), in 2 of the tests.

172. ; Stokes, R. A.; Ridgway, R. L.; and Kinzer, R. E. 1976. Slow-release formulations of aldicarb. Modeling of soil persistence. U.S. Agric. Res. Serv. [Rep.] ARS-S-103, 6. pp.

Theoretical models developed from data on the persistence of aldicarb in soil

were used to predict the requirements for slow-release formulations. The predictions indicated that a slow-release formulation will only be effective if the amount applied exceeds the amount necessary for initial control of a pest population. Also, a slow-release formulation may be the most effective against the insect pests that are most susceptible to a compound. An effective slow-release formulation should decrease the adverse effects of aldicarb on seedling emergence after soil applications. Controlled biological tests with cotton, boll weevils, aphids, and spider mites confirmed the model predictions.

173. Cowan, C. B., Jr., and Davis, J. W. 1967. Systemic insecticides for control of the boll weevil and the cotton fleahopper. J. Econ. Entomol. 60: 1038-1041.

In field experiments Temik®, a 10% granular formulation of UC-21149 (2-methyl-2=(methylthio) propionaldehyde O-(methylcarbamoyl)oxime) applied in the furrow when the cottonseed was planted, controlled thrips, Frankliniella spp., for 5-6 weeks and the cotton fleahopper, Psallus seriatus (Reuter), for about 9 weeks after planting. Used as a sidedressing, Temik gave control of the overwintered boll weevil, Anthonomus grandis Boheman, that was comparable to that of 2 foliar applications of azinphosmethyl and seasonal control of the cotton fleahopper. Although populations of Heliothis spp. remained light and below damaging levels, more eggs and larvae were found in the terminals, and more injured squares and bolls were found on cotton plants side-dressed with Temik than were found on untreated plants or on plants treated with azinphosmethyl. Also, 1 application of Azodrin® (3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate) to the stems of cotton plants at 0.5 lb per acre gave seasonal control of the cotton fleahopper.

174. ——, and Davis, J. W. 1968. Field tests with conventional low-volume or ultra-low-volume sprays for control of the boll weevil, bollworm, and tobacco budworm on cotton in 1967. J. Econ. Entomol. 61: 1115-1116.

All materials gave good control of the boll weevil, Anthonomus grandis. However, more effective insecticides are needed for control of Heliothis spp. on cotton, especially when a high percentage of the population is the tobacco budworm. Even with as many as 11 applications of large doses of experimental and recommended insecticides, there was considerable loss in yield to Heliothis spp.

175. Cross, W. H. 1973. Biology, control and eradication of the boll weevil. Annu. Rev. Entomol. 18: 17-46.

The review summarizes developments since 1965 which hopefully are leading toward eradication. It deals with: (1) the basic studies in biology, life history, and behavior; (2) the application of this information to control; and (3) the combination of the most promising methods in an overall eradication program.

176. ——. 1974. Importance of dispersal and migration of the boll weevil to an eradication program. Proc. 1974 Beltwide Cotton Prod. Res. Conf., p. 130.

The knowledge of rates of dispersal and distances over which boll weevils move by the several generations of adults as well as collectively during the season is important to planning widths of buffer zones in eradication attempts. Many observations by various entomologists since 1894 through experiments completed during the 1973 season indicate that the boll weevil has the capacity to disperse and migrate as an airborne adult. The most extreme example (season of 1909) was an advance of 120 miles through previously uninfested areas of Mississippi apparently largely as a result of wind transport by cyclonic storms. More noticeable advance in the direction

of prevailing winds and an average gain of 50 miles annually was the rule during the boll weevil's 30-year march across the U.S. Cotton Belt. Mechanical dispersal by man was probably minimal compared to this natural dissemination. The flight ability of the boll weevil has been substantiated by sustained flying to 11 miles on a flight mill and by the capture of adults to 2000 feet altitude. In the last 10 years boll weevils have been found in previously uninfested cotton presumably due to natural flights of at least 50 miles in West Texas and of 35 miles in Louisiana. A boll weevil was trapped in Chihuahua, Mexico 45 miles from cultivated cotton. Marked native weevils have been recaptured on several occasions at distances of 20 and 25 miles from the point of release and one female was retrapped 33 miles away 27 to 33 days after release. Dispersal by emerging overwintered boll weevils is considerable, especially when cotton is not replanted near the hibernation site. The most distant migration occurs in the last reproducing generation, most notably by the females. An influx beginning this year on August 15 into the core of the Pilot Boll Weevil Eradication Experiment area was the result of migration by this generation.

177. ———. 1976. History of the boll weevil problem. In Boll Weevil Suppression, Management, and Elimination Technology. Proc. of a Conference, February 13-15, 1974, Memphis, Tenn. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 1-2.

Before the 1890's we did not know there was a boll weevil. Pre-Columbian Indians in Central America and Mexico may have known of its damaging cotton, but we can find little evidence of it except for an adult specimen found in a Gossypium hirsutum L. boll fragment from Oaxaca, Mexico, in diggings dated 900 A.D. If Spanish Americans had boll weevil problems before the middle 1800's no record has been seen. The earliest known record of the boll weevil did not even connect it with cotton. It was described by

C. H. Boheman in 1843 as Anthonomus grandis from an adult collected 1831-1835, and labeled "Veracruz" with no host record. It crossed the Rio Grande in 1892 and reached the shores of Virginia in 1922. As already mentioned, early emphasis was placed on mechanical and cultural control. Even in 1910 the basic biology of the boll weevil was well understood, and its more important natural enemies were known. But interest in biological studies and biological control diminished in the 1930's when calcium arsenate was first used as an effective control of the boll weevil. Later, in the mid-1940's, the highly persistent arsenate was replaced by a combination of DDT and toxaphene and related compounds. When DDT was banned in 1972 by the Environmental Protection Agency because of its persistence, it was fortunate that organophosphate compounds such as methyl parathion, Guthion, and malathion were available. But the ever-present threat of the weevil's developing resistance to insecticides and the concurrent price we pay in killing off predators and parasites of other cotton insects (especially the bollworm and tobacco budworm) have led to the recent emphasis on an integrated program against the boll weevil.

178. . 1976. Relative populations and suggested long-range movements of boll weevils throughout the area of the Pilot Boll Weevil Eradication Experiment as indicated by traps in 1973. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tenn. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 103-107.

During 1973, Leggett traps were used extensively for survey of native overwintered and subsequent generations of the boll weevil throughout the area of the Pilot Boll Weevil Eradication Experiment (PBWEE) to indicate relative population levels and long-range movement in the different zones. Trap sites were located in radiating lines at 5-mi intervals from Morgantown, Miss., near the center of the core (zone I). Some changes in trap sites were located

in zones III, IV, V, and the northeast corner of II. By May 2, 40 sites were established one or more miles from cottonfields and 32, adjacent to 1972 or 1972-73 cottonfields. During May, 27 additional noncottonfield-oriented sites were located in or near zones I and II. Through August 1, these 99 sites each included 10 traps (placed 20 to 35 ft apart in a row) which were checked for weevils and rebaited with grandlure weekly. It is concluded that at least most of the adult boll weevils captured by noncottonfield-oriented traps in zone I during June, and again in August, were migrants from outside the area. This is supported by the negative captures before both of these periods, and by the gradient of decreasing captures toward the center of zone I during the periods. Of more interest, however, is the fact that 28 noncottonfield sites in zones I and II captured no weevils during the last week in July, while in the same period, 11 of 38 noncottonfield-oriented sites in zones III, IV, and V captured weevils.

179. , and Chesnut, T. L. 1971. Arthropod parasites of the boll weevil, Anthonomus grandis. 1. An annotated list. Ann. Entomol. Soc. Am. 64: 516-527.

Of 42 species of arthropods that parasitize the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae), 33 are Hymenoptera, 6 are Diptera, 1 is Coleoptera, and 2 are Acarina. Notes on other hosts, distribution, and natural history are included.

180. , and Hardee, D. D. 1968. Traps for survey of overwintered boll weevil populations. Coop. Econ. Insect Rep. 18: 430.

In studies at the Boll Weevil Research Laboratory, traps baited with live male boll weevils (Anthonomus grandis) are being developed as a method of survey for survival of overwintered boll weevil populations. Traps of two types were superior to several others. A Stikem®-coated wing trap is

satisfactory for general survey. An oblique funnel trap, 4 x 4 x 6 in. is preferred when trapping live weevils is desired. Both traps are baited with five male weevils in small individual cages.

181. ; Hardee, D. D.; and Nichols, F. 1967. Punch cards in attraction and population studies of boll weevils. J. Econ. Entomol. 60: 484-485.

In sexes of the boll weevil, Anthonomus grandis Boheman, a system of color coding the adults has provided an efficient method of keeping sequential records on individual weevils. However, when varying numbers of observations of marked weevils in a population were made over a period of hours or days, it became progressively more difficult to locate the data sheets for the individual weevils. Punch cards (5 x 8-in. Unisort Analysis Cards®) divided into categories have 1 side with 5 positions that can be used to color code the weevils. Thus we can rapidly find individual weevil records from populations of as much as several hundred individuals. Other categories on the card that allow rapid summaries of data are: sex, larval diet, release test number, capture test number, biological notes, feet moved, attracting source, and type of response.

182. ; Hardee, D. D.; Nichols, F.; Mitchell, H. C.; Mitchell, E. B.; Huddleston, P. M.; and Tumlinson, J. H. 1969. Attraction of female boll weevils to traps baited with males or extracts of males. J. Econ. Entomol. 62: 154-161.

When female Anthonomus grandis Boheman in large plots or cages were captured in 12 kinds of traps, all baited with males or various extracts of males, a small Stikem®-coated plywood trap and a Plexiglas® screen funnel trap proved to be the most efficient designs. Few or no females responded to empty traps (controls), and a preponderance of captured females came to the traps from downwind. Thus, a wind-borne sex attractant is produced by male boll weevils.

The captures of females indicated a preference for live males over extracts of males of 1.8:1 when the comparisons were made on different days and of 6.2:1 when they were made on the same day.

183. ; Leggett, J. E.; and Hardee, D. D. 1971. Improved traps for capturing boll weevils. Coop. Econ. Insect Rep. 21: 367-368.

Large numbers of male or pheromone-baited traps for capturing of boll weevils (Anthonomus grandis Boheman) have been employed for the past several years in survey and control programs of the Entomology Research and Plant Protection Divisions, ARS, USDA, and other agencies. Results of a series of tests conducted at the Boll Weevil Research Laboratory determined colors most attractive to the boll weevil, as well as more efficient and economical trap designs. From 1966 through 1968, a Stikem® (Michel and Pelton Co.) coated plywood wing trap painted John Deere Green (Mobile Paints B.L.P. Rus-Kil), and an oblique funnel live trap were used in a variety of circumstances and determined to be the best designs for capturing boll weevils (1970). Results of tests in 1968 indicated that white or bright yellow traps were more attractive to boll weevils than the darker green traps. Boll weevils as well as many other insects are greatly attracted by the intensively reflective daylight fluorescent pigments with peak emission in the 525 mμ region of the spectrum. Tests conducted late in 1970 with traps of several shapes made from plastic-impregnated paper half-gallon cartons resulted in the development of a disposable and more economical trap. A trap of a foldout design, 19 cm wide x 25.5 cm high, was constructed by trimming unformed cartons and stapling 2 inside out and back to back to form 4 wings. Saturn Yellow paint mixed 3:1 with turpentine was rolled on the inner white surface of the cartons before stapling. Stikem® or Tack-Trap® (Animal Repellents, Inc.) under pressure was applied to the wings with a flange nozzle tip 8 cm wide.

184. ; Lukefahr. M. J.; Fryxell, P. A.; and Burke, H. R. 1975. Host plants of the boll weevil. Environ. Entomol. 4: 19-26.

Principal plant hosts of Anthonomus grandis Boheman are in 4 closely related genera of the Malvaceae: Gossypium, Cienfuegosia, Thespesia, and Hampea. After Gossypium, the most important host in the United States is Cienfuegosia drummondii (Gray) Lewt. in Southern Texas. However, the complexity of hosts increases in tropical areas. Plant species first reported herein as hosts of the boll weevil are: Gossypium harknessii Brandg., G. lobatum Gentry, G. laxum Phill., Cienfuegosia rosei Fryx., Hampea rovirosae Standle., and Pseudabutilon lozani (Rose) R. E. Fries.

185. , and McGovern, W. L. 1969. New parasites, Zatopis perdubius and Megaselia aletiae, of the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 62: 674.

Recent summaries of the literature and surveys for parasites of the boll weevil, Anthonomus grandis Boheman, disclosed that 42 species of arthropods parasitize the boll weevil. These studies added much information about the range and relative importance of several species of boll weevil parasites, but only 2 species were found for the 1st time as parasites of the boll weevil.

186. ; McGovern, W. L.; and Cross, E. A. 1975. Insect hosts of the parasitic mites called Pyemotes ventricosus (Newport). J. Ga. Entomol. Soc. 10: 1-8.

A survey of the bibliography of mites called Pyemotes ventricosus (Newport) [often called the straw itch mite] revealed 133 recorded insect hosts and six more are reported here for the first time. Damage to immature stages and teneral or soft-bodied adult insects of many species may be light or may be severe enough to eliminate segments of host populations completely.

187. ; McGovern, W. L.; and Mitchell, H. C. 1969. Biology of Bracon kirkpatricki and field releases of the parasite for control of the boll weevil. J. Econ. Entomol. 62: 448-454.

Bracon kirkpatricki (Wilkinson), braconid parasite of larvae of several lepidopterous species that occurs widely in tropical regions of Africa, was introduced into Texas, northern Mexico, and Puerto Rico in the 1930's and 1940's in an attempt to control the pink bollworm, Pectinophora gossypiella (Saunders), but it did not overwinter successfully. In 1935, J. W. Folsom demonstrated parasitism of the boll weevil, Anthonomus grandis Boheman, by B. kirkpatricki in an insectary at Tallulah, La., and recorded his observations which are summarized in this paper. In 1966, live adults and cocoons were received from Kenya by the USDA Boll Weevil Research Laboratory. Since then, a colony has been maintained continuously by using larvae of the boll weevil as host material. Several recent releases in the field produced varying percentages of parasitism of boll weevils.

188. , and Mitchell, H. C. 1966. Mating behavior of the female boll weevil. J. Econ. Entomol. 59: 1503-1507.

Mating behavior of the boll weevil, Anthonomus grandis Boheman, was observed in isolated cottonfield plots in Florida and Mississippi. Males did not respond to females over distances greater than 1 or 2 inches, but females often sought males at distances of more than 30 feet, especially from downwind positions. Elaborate tactile behavior by the female was common in inducing males to mate. Successive multiple matings were noted for both sexes.

189. , and Mitchell, H. C. 1968. Parasites of the boll weevil in Mexico. VI National Entomological Congress Organized for the Society of Mexican Entomology, 23-26 October 1967. Folia Entomol. Mex. 18-19: 24.

Over 40 species of arthropods have been reported as parasitizing the boll weevil (Anthonomus grandis Boheman) throughout its range. Of these about 14 species are now known to occur naturally in Mexico. Most records are of a qualitative nature and for a limited number of localities. A tarsonemid mite, Pyemotes ventricosus (Newport), has been reported attacking the boll weevil in areas of northern Mexico. All others found have been in the insect order Hymenoptera. The following have emerged from boll weevil infested cotton squares or bolls from one or more localities in Mexico: the braconids Urosigalphus schwarzi Crawford#, Aliolus curculionis (Fitch)#, Bracon mellitor Say, and Bracon sp.: the ichneumonid Calliephialtes thruberiae Cushman, the eulophid Tetrastichus hunteri Crawford#; the eupelmid Eupelmus sp.#; the torymid Microdontomerus anthonomi (Crawford)#; the pteromalids Heterolaccus grandis Bruks. Heterolaccus hunteri (Crawford), and Zatropis incertus (Ashmead) #; and the eurytomids Eurytoma herrerae (Ashmead) and Eurytoma tylodermatis Ashmead#. (#Seven of these species are here reported apparently for the first time in Mexico.)

190. , and Mitchell, H. C. 1969. Distribution and importance of Heterolaccus grandis as a parasite of the boll weevil. J. Econ. Entomol. 62: 235-236.

The known distribution of Heterolaccus grandis Burks, a pteromalid parasite of the boll weevil, Anthonomus grandis Boheman, was extended from the original type-locality in Nicaragua to Costa Rica, Guatemala, and 3 States in Mexico. Observations since 1961 indicate that H. grandis may be the most important parasite of the boll weevil on the Pacific slope of Mexico and Central America. The most recent record establishes the occurrence of H.

grandis in the humid east coast of Mexico in Veracruz, where it was found parasitizing boll weevils on a newly discovered host plant, Hampea sp. Association of H. grandis with H. hunteri (Crawford) and with Urosigalphus schwarzi Crawford is mentioned.

191. ; Mitchell, H. C.; and Hardee, D. D. 1976. Boll weevils: Response to light sources and colors on traps. Environ. Entomol. 5: 565-571.

The response of Anthonomus grandis Boheman to colored lights in the laboratory confirmed that the 5-00-525-nm region of the spectrum has the greatest attraction. Poor response to red was noted in the laboratory and in the field. In the field, the response of both early- and late-season boll weevils to the traps increased as the intensity of reflected light was increased and also when the pigment more closely approached the 500-525-nm region of the spectrum. The greatest response was obtained with highly reflective daylight fluorescent pigments that had this spectral characteristic.

192. Culp, T. W. 1979. Registration of Pee Dee 695 and Pee Dee 875 germplasm lines of cotton. Crop Sci. 19: 751.

Two breeding lines of cotton (Gossypium hirsutum L.), Pee Dee 695 (GP 42) and Pee Dee 875 (GP 43), were released by AR, SEA, USDA and the South Carolina Agricultural Experiment Station in 1978. Both breeding lines possess resistance to the bollworm (Heliothis zea Boddie) and the tobacco budworm (H. virescens Fab.). Pee Dee 695, a frego bract line, is also resistant to the boll weevil (Anthonomus grandis grandis Boheman).

193. , and Harrell, D. C. 1979. Registration of Pee Dee 6520 germplasm line of cotton. Crop Sci. 19: 752-753.

Pee Dee 6520 has given above-average performances in tests where yields are influenced by injury from boll weevil (Anthonomus grandis grandis Boheman);

bollworm (Heliothis zea Boddie); or tobacco budworm (H. virescens Fab.). Its superior performance may be due to rapid fruiting and a shorter exposure of tender fruiting parts to insect attacks. The prolific nature of Pee Dee 6520 may partially compensate for insect injury to fruiting parts, because they are replaced more rapidly in this line than in other cultivars. Seed (25 g) of this breeding stock may be obtained from AR, SEA, USDA, Pee Dee Experiment Station, Florence, SC 29503.

194. Curry, G. L.; Sharpe, P. J. H.; DeMichele, D. W.; and Cate, J. R. 1980. Towards a management model of the cotton-boll weevil ecosystem. J. Environ. Manage. 11: 187-223.

A model of the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae), cotton, Gossypium hirsutum L. (Malvales: Malvaceae), crop ecosystem is presented. Indications are given of its utility in analyzing various control strategies such as pesticide timing, host plant resistance tactics and natural predation and parasitism. The insect component incorporates temperature-dependent development, reproduction and survival, including their stochastic variabilities. The cotton crop model is based on an average plant model consisting of the number of flower buds and bolls in each age category. Bud initiation rates, aging, and natural and photosynthate determined shedding of both buds and bolls are considered. The initiation rates and plant capacities can be varied to mimic plant genotype responses under a variety of soil and climatic conditions. The crop-insect interaction components consist of insect searching behavior and preference for egg deposition sites, shedding of infested fruit (buds and young fruit) and fruit drying as it relates to boll weevil larval mortality. The boll weevil-cotton crop model predicts the yield of both unattacked and infested crops for comparative purposes. Cost comparisons based on the proportional yields facilitate a quantitative analysis of the

various control strategies. Extensive validation of the individual subcomponents as well as the composite model are documented. The model, written in APL, uses 64K of core and simulates a season from first bud initiation to harvest in c. 1/sec on the AMDAHL 470 V/6 and IBM 370/168 computers. The computer cost of such an analysis is less than $2.

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195. Dadd, R. H. 1973. Insect nutrition: current developments and metabolic implications. Annu. Rev. Entomol. 18: 381-420.

Though there are many obvious lacunae in current systematic insect nutrition, nevertheless prime interest follows two other directions. One is toward ecological nutrition: the attempt to relate what the insect (or populations of insects) requires to what its natural environment can provide as food. This ultimately involves not only a knowledge of an insect's nutritutional needs, phagostimulatory behavior, digestive and absoptive abilities, etc., but also a matching knowledge of the chemistry of potential natural foods, and considerations of the flux of both these and the insect's varying requirements at different seasons and life stages. The other direction of interest is the application of nutritional findings to clarify metabolic process and vice versa. In this survey of recent nutritional literature (mainly past 1963 and necessarily selective) I attempt to improve some form by discussing the subject from a metabolic point of view.

196. Daum, R. J.; Gast, R. T.; and Davich, T. B. 1969. Marking adult boll weevils with dyes fed in a cottonseed oil bait. J. Econ. Entomol. 62: 942-943.

Information needs on the behavior and movement of insect populations have prompted a search for mass marking field populations. Seventeen dyes were uniformly mixed at 3% with a cottonseed oil bait, fed to adults and examined

for varying postexposure times. The results indicated that Calco Oil Blue 1088, Alizarine Fast Blue RB, Oil Soluble Blue II, Blue No. 13897 and Calco Oil Red N-1700 caused distinct coloration and low mortality. However, for 14 days postexposure only Calco Oil Red N-1700 produced longlasting coloration.

197. , and McKibben, G. H. 1969. A vacuum probe for manipulating insects. J. Econ. Entomol. 62: 267-269.

A simple inexpensive vacuum probe was made from the plastic guard of a disposable spyringe to manipulate insects without harming them. The tip is cut off perpendicular to the body of the guard with a sharp knife or razor blade, and holes of the desired diameter are drilled in the tip of the shank. Then either a piece of rubber tubing 1/8 inch in diam. is inserted into the inner part of the base of the probe and held with glue or 1/4-in.-diam. rubber tubing is forced over the outside base of the guard. The rubber tubing is then connected to a vacuum source. A foot-operated solenoid valve that can open and close the vacuum line is highly desirable.

198. ; McKibben, G. H.; and McLaughlin, R. 1969. Development of the bait principle for boll weevil control: Calco Oil Red N-1700 dye for measuring ingestion. J. Econ. Entomol. 62: 370-375.

A simple and inexpensive technique for measuring ingestion by adult *Anthonomus grandis* Boheman is described. Identical results were obtained using both the chromic oxide method and a red dye (Calco Oil Red N-1700®). Recovery of dye injected into adult weevils averaged 98%. No evidence of metabolism of the dye for as long as 8 hr post injection was observed. The dye has no deleterious effects on the boll weevil, is easily recovered, and does not require the use of dangerous chemical prepared reagents, or a chemical reaction. Suggestions are made for formulating the dye to obtain uniform dispersions in aqueous media.

199. ; McLaughlin, R. E.; and Hardee, D. D. 1967. Development of the bait principle for boll weevil control: cottonseed oil, a source of attractants and feeding stimulants for the boll weevil. J. Econ. Entomol. 60: 321-325.

Boll weevil, Anthonomus grandis Boheman, made almost as many feeding punctures in agar plugs treated with crude cottonseed oil as in those treated with a water extract of cotton squares (flower buds). In a field-cage experiment, almost 80% of the adult weevil population was attracted to and fed on a pastelike bait formulation containing 16% crude cottonseed oil that was applied to vigorously growing cotton plants at a rate of 6-13 gallon per acre. The addition or deletion of a water extract of squares did not produce a detectable difference in the percentage of weevils feeding on the bait. Therefore, crude cottonseed oil is a nearly limitless and inexpensive source of both feeding stimulants and attractants for the boll weevil and can be used to form an effective bait that should provide a new method of control.

200. Davich, T. B. 1969. Sterile male-technique for control of eradication of the boll weevil, Anthonomus grandis Boh. In Sterile Male Technique for Eradication or Control of Harmful Insects; Proceedings, pp. 65-72. International Atomic Energy Agency, Vienna.

Sterile-male technique for control or eradication of the boll weevil, Anthonomus grandis Boh. Results of several field experiments to study the sterile-male technique for eradicating the boll weevil, Anthonomus grandis Boh., are reported. The weevils were sterilized by dipping the adults in a solution of apholate. Although eradication was not achieved in any tests, definite population suppression was obtained, indicating that the sterile-male technique is applicable for boll weevil eradication. One experiment utilizing gamma-radiation for sterilization is described.

201. . 1972. Effect of male-baited traps on populations of boll weevils. Folia Entomol. Mex. 23-24: 19. (In Spanish).

Studies were conducted in a reproduction-diapause control area in West Texas and in a diapause control area in East Mississippi on utilizing male-baited traps as a possible boll weevil suppression measure. In Texas, trap placement with respect to cotton, and the value of systemic-treated and untreated small trap plots of cotton was studied. In Mississippi the effect of trap density was studied. Trap catch results and the infestation levels found in the trapped fields will be presented. The factors which influenced the trap catches and the infestation levels will be discussed.

202. . 1976. Boll weevil sterility. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15 1974, Memphis, Tenn. U.S. Agric. Res. Serv. [Rep.]] ARS-S-71, pp. 53-58.

In 1966 we contracted the Southern Research Institute at Birmingham, Ala., to conduct an extensive screening program for new promising chemosterilants. During a period of 4 years they screened well over 3,000 candidate materials, some of which we are still following up to this day. Additionally, we had extensive cooperation from Agricultural Research Service laboratories in Fargo, N. Dak., Florence, SC., and Baton Rouge, La. A number of promising leads cam out of this cooperative program, and busulfan, the chemosterilant of choice at present, was found. They found that prolonged feeding of this material could cause male sterility in excess of 95%. Busulfan, if manipulated properly, can and will sterilize males without causing undue damage to either the vigor or libido of the weevils. It has two disadvantages: (1) it does not sterilize a high enough percentage of the females, which means that we have to separate the sexes, and (2) there is very little margin of error in the required concentration. In other words, the sterile dose and the lethal dose are quite close. A combination of busulfan and hempa appears to be

superior to busulfan alone.

203. ; Daum, R. J.; and McLaughlin, R. E. 1968. Development of a bait for boll weevil control and ecological studies. Folia Entomol. Mex. 18-19: 25. (In Spanish).

Crude cottonseed oil and ground cottonseed have been found to contain attractants and feeding stimulants for the boll weevil. They have been formulated, with other materials, to produce a bait. The effectiveness of the bait has been measured by incorporating pathogens, a chemosterilant, or a dye into the formulation and observing the effects of boll weevil populations. The pathogens, or the chemosterilant, greatly suppressed population build-up when compared with an untreated check. Approximately 70-80% of a field population became visibly marked when the bait contained a dye. Utilization of the bait in conjunction with pathogens, or a dye, may provide entomologists with a new tool in insect control, or for ecological studies, respectively.

204. ; Hardee, D. D.; and Alcala, J. M. 1970. Long-range dispersal of boll weevils determined with wing traps baited with males. J. Econ. Entomol. 63: 1706-1708.

Between July 22 and 26, 1968, 49 plywood wing traps baited with male boll weevils (Hardee et al. 1969b) were installed along the 200-mile stretch of the Pan American Highway from Juarez to Rancho California, about 12 miles north of Chihauhua, Mexico. A distance of 65 miles in this 200-mile stretch in which no cotton is grown provided opportunity to study long-range dispersal of the boll weevil with wing traps baited with male boll weevils. The traps were painted green, coated with the adhesive Stikem®, and each was baited with 5 laboratory-reared boll weevils sterilized with 9000 R radiation and fed cotton squares (flower buds) or pellets of artificial medium (Gast and

Davich 1966). Also, the male placed in the traps were dyed red internally by incorporating Calco Oil Red N-1700® in the larval diet. The acetone-paper strip method of identifying insects marked with the dye was used on all captured boll weevils to determine whether they were sterile males that had escaped, or native weevils. Traps were checked, and fresh males and food were provided at least once a week. Between Oct. 2 and 22, 1968, 11 boll weevils (4 ♂, 7 ♀) were captured on traps 25 miles from cotton, 3 (1 ♂, 2 ♀) 36 miles from cotton, and 1 (♂) 45 miles from cotton. All were dissected, checked for dye, and found to be dark gray, reasonably fat, and negative for dye; thus, they were unquestionably native boll weevils. Although the traps were operated from July 22 through Nov. 7, all captures were made in the first 3 weeks of October.

205. ; Merkl, M. E.; Mitchell, E. B.; Hardee, D. D.; Gast, R. T.; McKibben, G. H.; and Huddleston, P. A. 1967. Field experiments with sterile males for eradication of the boll weevil. J. Econ. Entomol. 60: 1533-1538.

From June 17 through August 26, 1964, 11 weekly releases of apholate-sterilized male boll weevils, Anthonomus grandis Boheman, were made in 9 cottonfields, (15.8 acres) that had been treated with insecticides the fall of 1963 to reduce the population of diapausing weevils. These weekly releases ranged from 3270 to 26,620 sterile weevils per acre (an average of 8200 per acre). Migrant weevils entering the release zone from other areas may have caused the program to achieve population suppression rather than eradication, though the release zone was surrounded by a 120-acre zone that had received the same fall treatment and was treated intensively with insecticides in 1964 and by another 115-acre buffer zone that was treated with insecticides in 1964. However, the apholate sterilized only an average 95.8% of the weevils and caused a substantial reduction in mating competitiveness. The release of the sterile males against the low-level population achieved by the 1963 fall applications reduced

the number of oviposition-punctured squares compared with the number in the other 2 zones. Also the percentage of infertile eggs, the numbers of live immature and adult weevils per acre in fruit, the numbers of adults on plants and in hibernation sites, the numbers of overwintered adults, and the levels of infestation during the 2nd year or season after the releases were terminated were considerably lower in the release zone than in the zone treated intensively with insecticides.

206. Davis, J. W.; Cowan, C. B., Jr.; and Parencia, C. R., Jr. 1967. Emergence of overwintered boll weevils from hibernation sites near Waco, Texas. J. Econ. Entmomol. 60: 1102-1104.

A high percentage of overwintered boll weevils, Anthonomus grandis Boheman, held in hibernation cages emerged by the middle of June each year (1940-58) in the Waco area of Central Texas. Also, a high percentage of overwintered weevils collected on flight screens or observed in cottonfields (1959-1966) had left their hibernation sites to enter cottonfields by mid-June.

207. ; Cowan, C. B., Jr.; and Parencia, C. R., Jr. 1975. Boll weevil: survival in hibernation cages and in surface woods trash in central Texas. J. Econ. Entomol. 68: 797-799.

Survival of Anthonomus grandis Boheman in surface woods trash at Waco, Texas, from 1960-73 ranged from 14.4% in 1968 to 100% in 1965. Those surviving in field cages from 1940-58 ranged from 0.02% in 1951 to 21.32% in 1941. The data concerning survival and time of emergence from hibernation sites in the spring are needed in planning boll weevil suppression or elimination programs for the Texas Blacklands.

208. ; Harding, J. A.; and Wolfenbarger, D. A. 1975. Activity of a synthetic pyrethroid against cotton insects. J. Econ. Entomol. 68: 373-374.

Laboratory tests with a synthetic pyrethroid, NIA-33297 (m-phenoxybenzyl cis, trans- (±)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarbosylate) indicated it was more toxic than methyl parathion against the tobacco budworm, Heliothis virescens (F.), the bollworm, H. zea (Boddie), and the boll weevil, Anthonomus grandis Boheman. In field tests, NIA-33297 gave control of Heliothis spp. equal to emthomyl and monocrotophos.

209. ; Wolfenbarger, D. A.; and Harding, J. H. 1977. Activity of several synthetic pyrethroids against the boll weevil and Heliothis spp. Southwest. Entomol. 2: 164-169.

LD_{50}'s of the cis- and trans-isomers of (R,S)- or (S)-[cyano(3-phenoxyphenyl) methyl] or (3-phenoxyphenyl)methyl-(2,2-dimethylethenyl) of dichloro or dibromo-2, 2-dimethylcyclopropanecarboxylate were determined by topical application of the materials alone or in various mixtures to laboratory and field-collected strains of the tobacco budworm, Heliothis virescens (F.), and to laboratory strains of the boll weevil, Anthonomus grandis Boheman, and the bollworm, H. zea (Boddie). The laboratory strain of the tobacco budworm was more susceptible to the isomers and to the mixtures of the isomers than the field-collected strain. FMC-45498-(NRDC 161, RU 22974) = (S)-[cyano (3-phenoxyphenyl)methyl] cis-(+)-3-(2,2-dibromeothenyl)-2,2-dimethylcyclopropanecarboxylate cis-(+)-permethrin-(NRDC 148, FMC-35171) = (3-phenoxyphenyl) methyl cis-(±)-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate were the most active of 10 pyrethroids tested against the field strain of the tobacco budworm; FMC-45498 was the most active against the bollworm. Permethrin-(NRDC 143, FMC-33297, PP-557) = (3-phenoxyphenyl)methyl cis, trans-(±)-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate, received in

2 isomeric mixtures 75:25 and 60:40 trans:cis was the most active against the boll weevil. This insect appeared equally sensitive to all isomers of the dichloro and dibromo pyrethroids. In field trials, FMC-45498 at 0.022 kg/ha was effective against the tobacco budworm; at 0.11 kg/ha, it was effective against boll weevils.

210. Dean, G., and Lincoln, C. 1976. Various small plot tests on control of cotton insects. Arkansas Farm Res. 25(January/February):1.

This article and an earlier article present results of small plot tests on cotton insect control. Some new chemical groupings show great promise in sprays for bollworm-budworm control. Addition of the ovicide chlordimeform [Galecron or Fundal] improved performance of certain insecticides for worm control, but not of others. There are promising new ovicides for egg kill of bollworm-budworm. Microgranules, and possible conventional granules, gave good bollworm-budworm control and promise certain fringe benefits. Alternatives to the use of organic phosphate insecticides for boll weevil control are in sight.

211. DeMichele, D. W.; Curry, G. L.; Sharpe, P. J. H.; and Barfield, C. S. 1976. Cotton bud drying: a theoretical model. Environ. Entomol. 5: 1011-1016.

This paper presents a theoretical analysis of the rate of water loss from abscised flower buds of cotton, Gossypium hirsutum L., under any given set of environmental conditions. The bud drying model provides a link between larval boll weevil, Anthonomus grandis Boheman, mortality, and crop environment. Derived from assumptions relating to diffusive water loss, the model shows excellent agreement with experimental results for buds ranging in initial weight from 0.2-0.7 grams. The bud drying model provides a means of calculating the drying time of abscised cotton buds for any given microclimate.

212. DeMilo, A. B.; Borkovec, A. B.; and McHaffey, D. G. 1972. Chemosterilants against the boll weevil. 2. s-Triazines. J. Econ. Entomol. 65: 1548-1550.

Of 122 derivatives of s-triazine tested as chemosterilants against Anthonomus grandis Boheman, 44 were active as oviposition inhibitors. Occasional reduction in egg hatch-ability or in emergence of the F_1 generation was a less reliable indicator of sterilizing activity than reduction in oviposition, even when treated males were crossed with untreated females. The relationship between structure and activity in the s-triazines revealed considerable differences between susceptibility of A. grandis and the house fly, Musca domestica L., to this class of chemosterilants. Because of the relatively low and impermanent activity of these compounds in A. grandis, the s-triazines do not appear to have a practical potential for controlling this insect.

213. ; Oliver, J. E.; Fye, R. L.; and Haynes, J. W. 1977. Styrylsulfonamides as chemosterilants against house flies and boll weevils. U.S. Agric. Res. Serv. [Rep.] ARS-NE-84, 7 pp.

Eleven styrylsulfonamides were effective sterilants against boll weevils and house flies when the compounds were added to the diet of adult insects. In boll weevils, 10 compounds markedly inhibited oviposition in females but high toxicity prevailed at most concentration. Five sulfonamides tested in house flies by feeding were effective sterilants. The most effective compounds for flies were (E)-N-(2,4-dinitro-1-naphthalenyl)-2-phenylethenesulfonamide (AI3-62771) and (E)-N-(2,4-dinitro-1-napthalenyl)-2-(2-thienyl)ethenesulfonamide (AI3-62959). Structure-activity relationships were inconclusive for this group of compounds.

214. ; Terry, P. H.; and Rains, D. M. 1978. Simple derivatization procedure for gas-liquid chromatographic analysis of diflubenzuron in pond water and for analysis of its trifluoromethyl analog penfluron in boll

weevils. J. Assoc. Off. Anal. Chem. 61: 629-635.

A simple and convenient gas-liquid chromatographic procedure involving electron capture detection is described for determining diflubenzuron (N-[[(4-chlorophenyl)amino]carbonyl]-2,6-difluorobenzamide) in pond water and for determining the uptake of penfluron (trifluoromethyl analog of diflubenzuron) by boll weevils sexually sterilized by this compound. Both compounds were quantitatively converted to their respective N-(trifluoroacetyl) anilines by treatment with trifluoroacetic anhydride and pyridien in benzene at 50-60°C. In boll weevil analyses, the procedure was quantitative for penfluron at concentrations involving microgram quantities, background interference necessitated a thin layer chromatographic cleanup prior to derivatization. This modification enabled the determination of 100 ng/weevil. Analysis for diflubenzuron in natural pond water gave excellent results. For example, diflubenzuron at 2, 0.2, and 0.02 ppm in pond water was recovered at 95, 82, and 98%, respectively. A mechanism describing the reaction is proposed.

215. Dominguez, R. Y. 1977. Effect of different climatic conditions on distribution of Anthonomus grandis in Mexico. Folia Entomol. Mex. 36: 34-35. (In Spanish).

The regions in which the boll weevil is considered to be an important pest are: El Fuerte and Guasane in Sinaloa; Matomoras, Mante and Tampico in Tamaulipes; Apetzingan in Michoacan; Iguala in Guerrero; in the States of Morelas and Oaxaca, in Chiapas, Tapachila and Tuxtla Gutienez. It is not considered an insect of importance: in Sonora, south of Nogales; in Chihuahua, Valle de Juaez, Delicias, Meaqui, Ojinaga and Presidio, in Derrango, Bermejillo and Nazeis, in Sinaloa, Villa Union; in Nayarit, Valle de Santiago Ixcuintla; in Jalisco, Ajutla; and in San Luis Patosi and Morelos.

216. Douglas, A. G. 1966. Selection in cotton for antibiosis to the boll weevil, Anthonomus grandis. J. Econ. Entomol. 59: 32-34.

Forty-five experimental cotton lines and 2 commercial varieties were evaluated for antibiosis to the boll weevil as measured by percent emergence of adult weevils from squares with oviposition punctures. Range of percent emergence was from 15.3 to 59.2 and differences were highly significant. Percent emergence was not correlated with number of squares with oviposition punctures or with weight of squares.

217. Dumas, W. T., and Gilliand, F. R. 1973. Nozzle arrangement for insect control. Ala. Agric. Exp. Stn. Highlights Agric. Res. 20(Summer): 1.

Yield data show that 1, 2 or 3 nozzle per row treatments yielded almost twice as much seed cotton per acre as the untreated check with little differences existing among the yields from the treated plots. In each of the 3 years of testing, all nozzle arrangements tested have resulted in equally good insect control and cotton yields.

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218 Earle, N. W. 1980. Heat induced paralysis in the adult boll weevil, Anthonomus grandis: Effect on reproduction and longevity. Environ. Entomol. 9: 309-310.

Boll weevils, A. grandis Boheman, remained paralyzed for 1-6-h following 5 min exposures to temperatures between 46 and 51 degrees. Males were slightly more tolerant than females. The 28-day survival of males that had remained comatose for approximately 1 day after exposure to 50 degrees C was no different than that of the controls. Females treated at this temperature remained paralyzed for 1-2 days, but then resumed normal feeding activity and laid almost as many viable eggs as the controls by the 7th day posttreatment.

219. ; Lambermont, E. N.; Burks, M. L.; Slatten, B. H.; and Bennett, A. F. 1967. Conversion of β-sitosterol to cholesterol in the boll weevil and inhibition of larvae development by two aza sterols. J. Econ. Entomol. 60: 291-293.

The results of these analyses showed that both groups of weevils converted a substantial amount of β-sitosterol to cholesterol. Diapausing weevils contained more total sterol, but the percent composition was almost identical for the 2 groups. Studies with C^{14}-cholesterol have shown that diapausing weevils contain about the same amount of free sterols as reproducing weevils but substantially more sterol esters.

220. , and Leopold, R. 1975. Sterilization of the boll weevil: Vacuum fumigation with hempa combined with feeding busulfan-treated diet. J. Econ. Entomol. 68: 283-286.

Vacuum fumigation of Anthonomus grandis Boheman with hempa at 0.05-0.1 mm Hg at 21-23°C followed by a 4-day feeding period on diet containing 0.1% busulfan consistently sterilized both sexes. Pheromone production in males was not reduced, and 3-wk mortality was less than 40%. Young unfed weevils were very susceptible to hempa as well as to the lethal effects of high vacuum, but feeding for at least 1 h on 5% sucrose reduced the vacuum-induced mortality without affecting sterility. Chemical analysis of weevils soon after treatment showed residues of 498±355 μg of hempa/weevil. Prompt rinsing with water removed most of the hempa from the weevils and greatly reduced the sterility caused by the hempa treatment.

221. ; McGovern, W. L.; and Kearney, J. F. 1979. Pattern of distribution of ^{32}P-tagged, sterile male boll weevils dropped by plane. J. Ga. Entomol. Soc. 14: 269-277.

Boll weevils, Anthonomus grandis Boheman, were sterilized by gamma irradiation in an atmosphere of nitrogen followed by a dip in an acetone solution of diflubenzuron. Both sexes were relased, but only the males were tagged with ^{32}P. The weevils fell in a band no wider than 3m when dropped over cotton from a plane flying at a height of 15m. Many of the weevils landed on the ground, and a good portion of these died during the next 2 days, especially in parts of the field where the plants offered the least shade. The acetone treatment is believed to have partially inhibited flight capability, thereby preventing many weevils from reaching the cotton plants. Once the males began to feed, few of them moved from one row to the next.

222. , and Nilakhe, S. S. 1977. Radiosensitivity of different stages of spermatogenesis in the boll weevil. Ann. Entomol. Soc. Am. 70: 229-233.

All cell stages of spermatogenic cells are found in the adult boll weevil, Anthonomus grandis Boheman. We irradiated males and then allowed them to mate daily with successive groups of virgin females. Variations in fertility and in numbers of sperm produced were used as a basis for measuring changes in resistance of germ cells to the induction of dominant lethal mutations and to cell death. As expected, the various cell stages were not uniformly resistant. Sperm utilized by males immediately after irradiation were mature at the time of treatment. High doses of gamma irradiation were required to suppress fertility, indicating a high degree of resistance to the induction of dominant lethal mutations. Matings between the 3rd and 4th days after irradiation produced the fewest progeny. Sperm maturing at this time probably developed from irradiated spermatids; this cell stage was about 10 times more sen-

sitive than mature sperm. Progeny development increased with the matings 6-7 days after irradiation, indicating that the early cell stages were relatively resistant as far as dominant lethal mutations were concerned. However, these immature cell stages were readily destroyed by irradiation. Sperm production between the 5th and 8th days after treatment with 2500 rad (sperm arising from cells treated 5-8 days prior to maturity) was reduced by about 70%, indicating extensive cell destruction even with a substerilizing dose.

223. ; Nilakhe, S. S.; and Simmons, L. A. 1979. Mating ability of irradiated male boll weevils treated with diflubenzuron or penfluron. J. Econ. Entomol. 72: 334-336.

Treatment of young males of Anthonomus grandis grandis Boheman with acetone solutions of diflubenzuron (Dimilin®, TH-6040), or penfluron impaired mating ability. Mating success was often reduced by as much as 40-50%. Affected males usually tried to copulate with virgin females but their movements were often poorly coordinated. They sometimes achieved a partial penetration of the aedeagus without transferring sperm. The males were unable to recover from this deficiency. This problem was largely eliminated when the males were allowed to age for at least 3 days before treatment. Diflubenzuron applied as a 0.1% acetone dip by itself failed to completely suppress the production of progeny by females. However, when combined with 8000 rad of gamma irradiation, progeny suppression was complete.

224. ; Padovani, I.; Thompson, M. J.; and Robbins, W. E. 1970. Inhibition of larval development and egg production in the boll weevil following ingestion of ecdysone analogues. J. Econ. Entomol. 63: 1064-1069.

Adult female Anthonomus grandis Boheman became permanently infecund, but males were not affected, when fed various analogues of ecdysone. A trihydroxy, 6-keto steroid was found to be particularly effective and was evaluated

extensively as a female chemosterilant. Egg production was suppressed when females fed for only 6 days on diet containing the trihydroxy compound. None of the weevils died, and there was little recovery of fertility. High temperatures during treatment and addition of a synergist to the diet favored the sterilizing action. The combined effects of γ-irradiation and steriod treatment were not completely additive, an indication that the 2 sterilizing agents acted on a common target. Also, the steroid seemed to antagonize the action of the chemosterilant busulfan (1,4-butanediol dimethanesulfonate) when both were given in the diet of the adults. When given in the larval diet, 3 ppm of the trihydroxy steroid lowered the yield of adults, and 10 ppm almost eliminated the formation of adults. Deformities occurred at all stages of development.

225. , and Simmons, L. A. 1979. Boll weevil: ability to fly affected by acetone, irradiation, and diflubenzuron. J. Econ. Entomol. 72: 573-575.

Observations in the field indicated that a large percentage of sterilized Anthonomus grandis grandis Boheman were unable to fly from the soil surface to nearby cotton plants. In laboratory tests, dipping in acetone or in an acetone solution of diflubenzuron reduced flight ability by ca. 40%. Irradiation alone did not affect flight, but joint treatment with irradiation plus acetone reduced the number of flights by ca. 72%. Diflubenzuron reduced flight when fed to newly-emerged adults on 4 consecutive days but not when fed on the 4th day only. This delayed dietary treatment with diflubenzuron, combined with irradiation with 10 krad in nitrogen, effectively suppressed female fertility and had a minimal effect on the flight ability and mating capability of males.

226. ; Simmons, L. A.; and Nilakhe, S. S. 1979. Laboratory studies of sterility and competitiveness of boll weevils irradiated in an atmosphere of nitrogen, carbon dioxide, or air. J. Econ. Entomol. 72: 687-691.

Almost all male Anthonomus grandis grandis Boheman treated with 7 krad of gamma irradiation in air were dead within 14 days but over half of the males irradiated in an atmosphere of nitrogen lived for at least 21 days. Males were still 98-100% sterile when allowed to mate 3 and 7 days after treatment with 7 krad in nitrogen; however, by the 10th day, sterility had dropped to ca. 85%. Dissections on the 21st day posttreatment revealed that many males had enlarged testes with sperm bundles, indicating that they had recovered fertility. A dosage of 10 krad in nitrogen was required to maintain a level of at least 99% sterility; at this dosage level, survival, sterility in both sexes, and male mating capability were the same as for 8 krad in air. In laboratory tests, sexual competitiveness of males exposed to 10 krad in nitrogen (0.85) was significantly higher than that of males exposed to 8 krad in air (0.51). These competitiveness values from the laboratory studies were much higher than the published figures for weevil competitiveness in the field (0.17-0.36). This lack of agreement indicates that not all of the significant factors associated with male competitiveness are measured by the usual laboratory tests.

227. ; Simmons, L. A.; Nilakhe, S. S.; Villavaso, E. J.; McKibben, G. H.; and Sikorowski, P. 1978. Pheromone production and sterility in boll weevils: Effect of acute and fractionated gamma irradiation. J. Econ. Entomol. 71: 591-595.

Each of 3 methods of irradiating male Anthonomus grandis Boheman resulted in a unique pattern of pheromone production over a 12-day period of observation. Peak pheromone production occurred 4-6 days after treatment in males given a single large dose of gamma irradiation (acute irradiation) at the age of 4

days and in males given small increments of irradiation (fractionated irradiation) during the late pupal and early adult stages. Both groups produced much less pheromone during the next 3 days. The acute irradiated weevils, destined to die soon, produced no pheromone after the 9th day, whereas the fractionally irradiated males began to show a partial recovery. Males fractionally irradiated entirely during the adult stage produced a moderate but constant amount of pheromone during the entire 12-day period. Measurements of attractiveness of treated males placed in field traps produced results that were in general agreement with the laboratory data. Male sterility for all 3 treatments was ca. 99%, and from 66-82% of the males were able to transfer sperm 7 days after treatment. Females irradiated during the pupal and adult stages were completely sterile, producing no eggs. The 2 groups of females irradiated as adults produced some eggs and it was necessary to incorporate a dip treatment consisting of 0.02% diflubenzuron (Dimilin®; N-[[4-chlorophenyl)animo]carboynl]-2,6-difluorobenzamide) in acetone to suppress viability.

228. ; Slatten, B.; and Burks, M. L., Jr. 1967. Essential fatty acids in the diet of the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae) J. Insect Physiol. 13: 187-200.

Larvae of the boll weevil (Anthonomus grandis Boheman) developed normally in diets without added fatty acids. However, the adults from the fat-deficient diets laid fewer eggs than normal. Egg production was highest when the diets of the larvae and adults of both sexes contained a mixture of triglycerides that included trilinolein or trilinolenin. Omission of triglycerides from the diet of the larvae influenced fecundity more than their omission from the diet of the adults. Symptoms of fat deficiency in adults were most pronounced when they were reared from eggs that were obtained from parents being fed with a diet low in fat. Gas chromatographic analyses of these eggs showed that they con-

tained only small amounts of linoleic and linolenic acids. The triglycerides added to the diet appeared to influence the synthesis and accumulation of other fatty acids in the weevil. The percent fatty acid composition of the males, females, and eggs were found to be very similar. The boll weevil did not require a dietary source of vitamin E. Weevils maintained for three generations on purified diets without added Vitamin E continued to lay large numbers of eggs.

229. ; Villavaso, E.; Ernst, N.; and Glover, D. 1976. Laboratory quality-control studies of sterility in boll weevils produced for the Mississippi Pilot Eradication Experiment. U.S. Agric. Res. Serv. [Rep.] ARS-S-128, 15 pp.

The Cotton Insects Physiology Laboratory, Baton Rouge, La., monitored the sterility of boll weevils (Anthonomus grandis Boheman) produced for mass release in a pilot eradication program in southern Mississippi. Weevils were reared and sterilized at the Robert T. Gast Laboratory, Mississippi State, Miss., during 1972 and 1973. Progressive increases in sterility coincided with improvements in the health and vigor of the weevils; an extension of the treatment period; the addition of a second chemosterilant, hempa, to the busulfan-treated diet; and refinements in the preparation and feeding of chemosterilant diets.

230. ; Walker, A. B.; and Burks, M. L. 1966. An artificial diet for the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae), based on the analysis of amino acids in cotton squares. Ann. Entomol. Soc. Am. 59: 664-669.

Diets suitable for larvae and adults of the boll weevil, Anthonomus grandis Boheman, were formulated from cotton flower bud protein and free amino acids in combination with other standard nutrients. Analyses of anthers of young

flower buds determined the quantities of protein and free amino acids to be included. Preliminary results indicated that the diet could be used to study the lipid requirements of the weevil. Naturally occurring lipids were effectively removed from the finely divided flower bud protein by Soxhlet extraction for 12 days. Pure fats and sterols were then added back to the diet to replace those removed. A uniform dispersal of lipids in the diet was accomplished by adding an ethyl ether solution of lipids to the dried protein. The ether was allowed to evaporate, and the lipid-coated protein was then mixed with the other diet ingredients. Larvae reared from this diet were larger than those reared from other less refined diets. Adults laid almost as many eggs in artificial diet as they did in fresh cotton flower buds.

231. ; Walker, A. B.; Burks, M. L.; and Slatten, B. H. 1967. Sparing of cholesterol by cholestanol in the diet of the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 60: 599-603.

Larvae of the boll weevil, Anthonomus grandis Boheman, required a minimum of 20 mg of cholesterol per 100 g of diet for normal development. They also developed normally when as much as half of this minimal amount was replaced with cholestanol. The larvae failed to develop in diets in which cholestanol was the only sterol present. Adults could not maintain a high rate of egg production when given a diet containing cholestanol as the only sterol. However, those eggs that were laid continued to hatch, even while egg production was declining. In contrast, eggs from weevils being fed a diet containing inadequate amounts of cholesterol, but no cholestanol, failed to hatch. Quantitative gas chromatographic analyses of sterols from eggs and adults revealed that the improved hatch resulting from the addition of cholestanol to the diet was not due to an increased carryover of cholesterol from the immature stages. The small amounts of cholesterol in eggs from cholestanol-

fed parents were effectively "spared" or supplemented by the relatively large amounts of cholestanol that were present; this sparing action enabled the embryo to survive. Sparing of cholesterol in the adult was less efficient, and as a result, egg production soon declined.

232. Eden, W. G. 1976. Report of Entomological Society of America Review Committee on the Pilot Boll Weevil Eradication Experiment. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 126.

We were deeply impressed with the vast amount of information about the boll weevil that was brought to bear upon the eradication attempt and the organization and execution of the logistical aspects of the experiment. We could not agree whether a distinction should be made between "accomplishing eradication" and "demonstrating feasibility of eradication." Eradication was not accomplished in the core area. It was demonstrated that populations of weevils can be reduced to extremely low levels by a regional suppressive program. We could not agree on whether technical feasibility of eradication of boll weevil populations was demonstrated. We believe the decision regarding attempted eradication of the boll weevil should and will be a socio-political decision. We recommend that a detailed summary of the program be published and that all concerned members of our society - and particularly entomologists - inform themselves as to the long-range environmental and economic benefits that would result from a successful eradication program and weigh those against the costs involved.

233. Flint, H. M.; Bibow, W. R.; and Lahren, C. K. 1966. Radiation studies with the boll weevil: lethal effects on larvae, pupae and adults; male sterility and dose fractionation. J. Econ. Entomol. 59: 1249-1255.

Larvae, puape, and adult weevils are very sensitive to X-rays, as measured by adult survival 3 weeks after irradiation. Adult survival of 50-70% 3 weeks after treatment was considered the minimum acceptable. Doses of X-rays that met this criterion were 1200 R for last-in-star larvae, 2400 R for late-stage pupae, and about 3200 R for adults. In adult weevils, mortality occurred about 7-14 days after irradiation, and the death rate did not increase when doses were increased from about 3200 to 15,000 R. Male weevils were 90 and 99% sterilized by doses of about 7500 and 9000 R, respectively. No sterilized male lived more than 3 weeks, and no increase in fertility occurred. In a test with mixed populations of adults irradiated with doses of as much as 4800 R, a significant increase in fertility occurred during the 3-week test period, but 5 days after doses of 4000 or more roentgens, egg production was almost eliminated. No increased survival occurred when 8000 R were administered in 4 fractions of 2000 R each to adults at intervals between fractions of as much as 48 hours. Both the lethal and sterilizing effects of X-rays were reduced when weevils in the larval, pupal, and adult stages were sequentially irradiated with various fractionated doses. Dose fractionation is not promising as a means of producing a sterile and viable weevil.

234. ; Earle, N.; Eaton, J; and Klassen, W. 1973. Chemosterilization of the female boll weevil. J. Econ. Entomol. 66: 47-53.

Forty-three compounds were tested for chemosterilant activity by feeding them to adult Anthonomus grandis Boheman; three compounds, 5 fluorouracil, picolinaldehyde thiosemicarbazone, and isoquinaldehyde thiosemicarbazone, reduced fecundity to 4% or less of the controls with no hatch of eggs and less than 15% mortality during 1-week posttreatment. Partial recovery of fecundity and fertility

occurred during the 2nd week posttreatment with these compounds. Of 8 compounds tested in mbination with busulfan (1,4-butanediol dimethanesulfonate), only 0.08-0.1% busulfan with 0.4-0.5% hempa showed promise. Treatment with this combination reduced fecundity to about 0.2 adult progeny per treated female crossed with untreated males, permanently sterilized males, and caused less than 50% mortality in 3 weeks.

235. ; Eaton, J.; and Klassen, W. 1972. The use of Fumidil-B to reduce microsporidium disease in colonies of the boll weevil. Ann. Entomol. Soc. Am. 65: 942-945.

When Fumidil-B® was fed to larval and adult boll weevils, Anthonomus grandis Boheman (Coleoptera: Curculionidae), to reduce the percent of weevils infected by a microsporidian (designated as 1069), a dose of 0.25% in the adult diet resulted in an average of 2% infected weevils (determined by presence of spores) at 2 weeks post-emergence compared with 21% infection of similar weevils fed diet without Fumidil-B. Longevity was not affected by this does, but fecundity and egg hatch were reduced to 32 and 76% of the control, respectively. Weevils from a diseased colony fed larval and then adults diets containing 0.15 and 0.0025% Fumidil-B, respectively, were 12% diseased compared with 86% of weevils reared and maintained on untreated diets.

236. ; Walk, E. L.; Klassen, W.; and Greenburg, D. 1971. Biological effects of irradiation with thermal neutrons on boll weevils fed boric acid containing boron-10^2. J. Econ. Entomol. 64: 1002-1008.

Studies were conducted to determine whether the boron reaction (n,α) could be used to increase the sterility induced in Anthonomus grandis Boheman by irradiation with thermal neutrons. When reared on larval diet containing 0.01 or 0.1% boric acid ($H_3{}^{10}BO_3$) and irradiated with fluences of 1.34 - 2.25 X 10^{13} $N_{th}/cm^2/sec$ X time = fluence) weevils showed no increased mortality or sterility

because of the boron. When fed diet containing 0.1% boric acid and irradiated with 1.53×10^{12}-1.50×10^{13} N_{th}, adult weevils had 10- and 2-fold greater mortality and sterility, respectively, than weevils fed regular diet and irradiated with the same fluences. Irradiation of males when fed boric acid caused greater sterility than in similarly treated females, although fecundity was reduced also in irradiated females. Males that survived 2-3 weeks recovered fertility. At least 0.01% boric acid was required in the adult diet to obtain increased mortality and sterility at 8.14×10^{12} N_{th} compared with irradiated males which were fed regular diet. Increased mortality was obtained when 1-4 days elapsed between feeding and irradiation, whereas increased sterility was obtained when no more than 2 days elapsed between feeding and irradiation. When fed 0.1% boric acid and irradiated with 25 krad cobalt-60 gamma rays, adult weevils had no increased sterility or mortality from the boric acid.

237. Flitters, N. E. 1968. Insect body temperatures determined with microthermoelectric thermometer. Ann. Entomol. Soc. Am. 61: 36-38.

The body temperatures of larvae of bollworms, Heliothis zea (Boddie), and adults of house flies, Musca domestica L.; boll weevils, Anthonomus grandis Boheman; American cockroaches, Periplaneta americana (L.); and brown soft scale, Coccus hesperidum L., were determined with microthermocouples and continuously recorded on a 24-point potentiometer. Peak body temperature for scales was 121°F, for cockroaches 124°F, bollworm larvae 118°F, for house flies 112°F, and for boll weevils 106°F. Ambient air of the microenvironmental at 5 ft above ground was checked for comparison.

238. Frisbie, R. E. 1976. Role of pheromone traps in survey, detection, program evaluation, and related biological studies. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 32-36.

It is apparent that the boll weevil pheromone trap is extremely useful in detecting incipient populations of boll weevil for survey and detection. The information generated on relative seasonal abundance and movement has merit for use in boll weevil control programs. The boll weevil pheromone trap also has been helpful in the evaluation of boll weevil suppression programs when comparing infested to uninfested cotton. Its use in pinpointing deficiencies within these programs has been proved. As yet, sufficient information is not available to totally rely on trap catches when quantitatively comparing one area of boll weevil infested cotton with another. Currently, one must support trap catches with manual field counts to validate such a comparison. In the future and if trap catches can be related to absolute field counts, the boll weevil pheromone trap will increase in value in the battle against this pest.

239. ; Sprott, J. M.; Lacewell, R. D.; Parker, R. D.; Buxkemper, W. E.; Bagley, W. E.; and Norman, J. W. 1976. A practical method of economically evaluating an operational cotton pest management program in Texas. J. Econ. Entomol. 69: 211-214.

Procedures to determine the economic validity of an operational pest management program were devised. An economic evaluation using the Texas cotton pest management program as a prototypic example showed increased per acre net returns by program participants over nonparticipating producers of $55.31, $17.95, and $30.59 in the Rio Grande Valley, Blacklands, and Trans-Pecos program areas, respectively, in 1973. In 1974, per acre net returns were increased by $15.72, $18.90, and $54.13 for the same 3 respective areas.

240. Fryxell, P. A. 1974. The unresolved mystery of Cienfuegosia intermedia. Southwest. Nat. 18: 479-481.

Cienfuegosia intermedia Fryx. was described on the basis of a single specimen discovered in the Leiden herbarium (L.). The label says only: "Mexico, Mendes, 2" and includes a set of initials that can be interpreted as "HB DC." It was not known then (nor is it now) if "Mendes" refers to the collector or to a locality. Recently, a second specimen of this species has been discovered in the herbarium of the University of Texas (TEX). Its label says: "Mexique, Leon, Bdr., 1844." A subsequent annotation adds: "Bdr. = Berlandier." Cienfugosia intermedia occurs in northern Mexico and is critically situated geographically for possibly playing a role in the spread of the boll weevil from the tropics to the cotton belt in the southeastern United States.

241. , and Lukefahr, M. S. 1967. Hampea Schlecht.: possible primary host of the cotton boll weevil. Science 155: 1568-1569.

The boll weevil severely infests buds in natural stands of Hampea sp. in Veracruz, Mexico. The geography and ecology of these trees suggest that they may be the long-sought primary host of the boll weevil.

242. Furr, R. E., and Merkl, M. E. 1967. Residual toxicity of three phosphorus insecticides to the boll weevil. J. Econ. Entomol. 60: 748-750.

The residual toxicity of 3 phosphorous insecticides to the boll weevil, Anthonomus grandis Boheman, was determined hourly for 24-48 hours by using field cages made of ice cream cartons. The cages were an improvement over those formerly used and should facilitate such studies of similar chemicals and insects. Azinphosmethyl at 0.25 lb per acre was effective for 12-24 hours and at 0.5 lb per acre, for more than 24 hours. Methyl parathion at 0.25 and 0.5 lb per acre was effective for only 2-4 and 4-6 hours, respectively. Malathion at 0.5 lb per acre gave

residual kill for 4-6 hours; at 2 lb per acre it was effective for more than 24 hours.

243. Fye, R. E. 1968. Populations of boll weevil in selected fields in Arizona in 1965 and 1966. J. Econ. Entomol. 61: 377-380.

Surveys of boll weevils, Anthonomus grandis Boheman, in selected cottonfields in Arizona in 1965 and 1966 indicated infestations of the boll weevil were widespread. Populations were greater in 1965 than in 1966, and larger populations occurred in stub cotton than in planted cotton. The boll weevil complex in cultivated cotton in Arizona attacks bolls throughout the season. Large populations of potential overwintering weevils in bolls were destroyed with stalk shredders and clean plowing.

244. . 1968. Spread of the boll weevil by drainage water and air currents. J. Econ. Entomol. 61: 418-424.

When conditions are ideal, the thurberia weevil, Anthonomus grandis thurberiae Pierce, may be moved in thurberia bolls in flood drainage water from the mountainous areas where thurberia grows into the valleys where cotton is cultivated. However, the necessary conditions seldom occur. Tests in the laboratory indicated that vertical air velocitites of 2.5-5.5 meters per second are necessary to suspend passive boll weevils, A. grandis Boheman, and that velocities in excess of 31.3 meters per second may be needed to free a weevil from its foothold on cotton leaves. In the later summer in Arizona and northern Sonora, Mexico, the necessary air turbulences (thermal convection and dust devils) are present to elevate boll weevils into the upper wind currents. Then these upper wind currents and their associated turbulences could move the weevils in the direction of the airflow.

245. . 1968. The thurberia weevil in Arizona. J. Econ. Entomol. 61: 1264-1268.

Overwintering Anthonomus grandis thurberiae Pierce were released from the bolls of wild cotton by summer rainfall totaling 4-7 inches. Emergence is poorly timed with the fruiting of the native host, Gossypium thurberi Todaro, and the emerged weevils are forced to feed on the developing foliage for an extended period. An early generation develops in thurberia squares. Factors affecting mortality of the weevil populations include the physiological conditions of the thurberia plant, grazing of cattle, destruction by ground squirrels, predators, and parasites.

246. . 1969. Longevity and fecundity of the boll weevil complex in Arizona. J. Econ. Entomol. 62: 1408-1412.

Adult boll weevils, Anthonomus grandis Boheman, collected from cultivated cotton in Arizona lived an average of 6 months in the laboratory, and a few lived as long as 11 months; in the field this longevity was abbreviated. Thurberia weevils, A. grandis thurberiae Pierce, were longer lived than weevils from cultivated cotton, and overwintering thurberia weevils lived longer than the 1st square-reared generation. The fecundity of Arizona boll weevils was highly variable, and the potential was drastically reduced in the field. The ovipositional pattern of weevils from cultivated cotton was relatively consistent and apparently was closely associated with longevity.

247. . 1972. Preliminary investigation of vertical distributions of fruiting forms and insects on cotton plants. J. Econ. Entomol. 65: 1410-1414.

Many populations of fruiting forms and cotton insects found in the upper two or three 6-inch increments of cotton plants are correlated with popu-

lations in the remainder of the plants. However, the correlations are not of sufficient magnitude to allow estimates for the lower portions to be derived from counts made in the upper two or three 6-inch increments. From 70 to 100% of the insects observed were in the upper 2 feet of the plants.

248. . 1972. Relationship of temperatures to boll weevil complex populations in Arizona. U.S. Dep. Agric. Prod. Res. Rep. 136, 14 pp.

The major factor affecting the boll weevil complex (Anthonomus grandis Boheman) in Arizona is temperature. The development and mortality of individual weevils as well as the entire population are directly associated with the temperature in the oviposition sites and on the soil surface and indirectly with the heat input resulting in maturation of cotton plants. Individual weevil development, the population fecundity, longevity, and mortality and the maturing of cotton plants may be estimated with equations. These were developed with least squares analysis from several untransformed forms of cubic and quadratic, transformed forms of cubic and quadratic, the Fourier series, asymptotic, and logarithmic models. The equations accurately describe the relationship of the several phenomena with time or heat input. The boll weevils are suppressed by high temperatures during June, July, and frequently August, but their population increases as cooler fall temperatures ensue and the early maturing cotton bolls release an accumulated population of boll weevils to oviposit in late fruit.

249. , and Bonham, C. D. 1969. Estimating temperatures and heat flux in insect environments in stubbed cotton fields in the winter. J. Econ. Entomol. 62: 823-829.

Simple linear regression models of the temperatures of dry bolls, soil surface, cotton stalk trash, trash-soil interface, and growing tips from

cotton stubs on air temperature gave good estimates of temperatures and heat flux in the places that insects overwinter. Multiple linear regression models that included other variables such as moisture, trash depth, or boll diameters, usually improved the estimates.

250. , and Bonham, C. D. 1970. Analysis of populations of the boll weevil in one acre of cotton at Florence, South Carolina, in 1957-1959. J. Econ. Entomol. 63: 1505-1510.

Input of climatological factors (cumulative number of degree days above 55°F, mean and minimum relative humidities, cumulative number of rainy days, and cumulative rainfall) in 1 acre of cotton at Florence from 1957 to 1959, were linear in time during the 3 years. The deviations from the linear inputs provide an interpretive background for analyzing major changes in populations of Anthonomus grandis Boheman. Varying numbers of overwintering weevils in the climatic regimes of the 3 years resulted in population increases dependent upon the climatic inputs. Damage was poorly correlated with the number of adult weevils. Late-season migration was triggered by lack of oviposition sites in cotton squares.

251. , and Bonham, C. D. 1970. Summer temperatures of the soil surface and their effect on survival of boll weevils in fallen cotton squares. J. Econ. Entomol. 63: 1599-1602.

Mortality in populations of immature boll weevils, Anthonomus grandis Boheman, in fallen cotton squares commenced when the summation of the index of time (1-hour period) x temperature >38°C reached 60. All the weevils died when the summation reached 550. Soil surface in Arizona cottonfields attains a mean of 38°C when the mean in temperatures are 40°C. Soil surface temperatures of 38°C are common when air temperatures are lower than 30°C and may 60°C when air temperatures are at maximums. Frequent and prolonged periods

with temperatures >38°C impose a strong bioclimatic control on the boll weevils until late season, when shading by maturing cotton plants enables the survival of the immature weevils in the squares on the soil surface.

252. , and Bonham, C. D. 1971. Temperature in the plant parts of long-staple cotton. J. Econ. Entomol. 64: 636-637.

Temperatures of squares, bolls and terminal buds of long-staple cotton and the temperature within the squares, boll bracts, and cotton plant canopy were 2-5°F less than air temperature. The temperatures of plant bracts are highly correlated with air temperatures and may be estimated from air temperature with regression equations.

253. ; Cole, C. L., and Bull, D. L. 1970. Populations of boll weevils in selected fields in Presidio County, Texas, and Ojinaga, Chihuahua, Mexico, in late 1968 subsequent to reproductive-diapause control programs in 1965-1967. J. Econ. Entomol. 63: 1084-1086.

Surveys in August-October 1968 in areas in Presidio, Texas, and Ojinaga, Chihuahua, Mexico, that were treated in 1965-1967 in a reproductive-diapause control program against Anthonomus grandis Boheman indicated that the populations were increasing in several fields. The locations of these fields in the Rio Grande and Rio Conchos valleys are such that the weevils may soon repopulate the entire sprayed area if conditions are favorable.

254. ; Cole, C. L.; Tingle, F. C.; Stoner, A.; Martin, D. F.; and Curl, L. F. 1968. A reproductive-diapause control program for the boll weevil in the Presidio, Texas-Ojinaga, Chihuahua area, 1965-67. J. Econ. Entomol. 61: 1660-1666.

Control of the late-season reproductive generation and of diapausing Anthonomus grandis Boheman by aerial application of ultra-low-volume spray beginning in early September reduced overwintering populations to a very

low level. The 8 applications of malathion in 1965 and 1966 and the 8 applications of azinphosmethyl in 1967 protected the top crop. The program did not achieve eradication, probably because of the difficulty of thorough treatment of small farms and the high reproductive potential of the surviving weevils. The level of suppression achieved indicates that the method could be used to reduce populations low enough to permit delivery of a high ratio of sterile to surviving native weevils the following season.

255. , and Leggett, J. E. 1969. Winter survival in Arizona of thurberia weevils released from thurberia bolls. J. Econ. Entomol. 62: 467-470.

Anthonomus grandis thurberiae Pierce, released from hibernation cells in bolls of wild cotton, Gossypium thurberi Todaro, in December and February survived until late June and July. Longevity of released weevils increased when moisture was made available. However, a large percentage of weevils remaining in hibernation cells were still alove when all released weevils had died. In laboratory tests, released weevils readily moved to moist niches.

256. ; Leggett, J. E.; and Bonham, C. D. 1970. Winter survival of the boll weevil complex in Arizona. J. Econ. Entomol. 63: 1071-1074.

In Arizona, adult Anthonomus grandis Boheman from cultivated cotton emerged from buried and unburied bolls throughout the winter whenever the temperature exceeded the physiological threshold. Emergence was prevented by burying the bolls to a depth of 30 cm. A few weevils were found during the winter in desert trash adjacent to fields that had had large infestations the previous growing season. Most overwintering weevils in Arizona did not meet the criteria of full diapause associated with the southeastern boll weevil.

257. , and Parencia, C. R., Jr. 1972. The boll weevil complex in Arizona. U.S. Dep. Agric. Prod. Res. Rep. 139, 24 pp.

The data from the two eras (1920-30 and 1960) indicate a common conclusion. They show that the thurberia weevil may be a source of infestations, probably minor, in cultivated cotton where thurberia grows adjacent to cultivated cotton, but the history of relatively minor boll weevil infestations in the Santa Cruz Valley over the years suggests that the thurberia weevil is not a major menace to cultivated cotton. However, the boll weevil's presence in northern Mexico, which was apparently responsible for heavy infestations in recent years, may be a threat to the top crop produced in late fall in Arizona. Both the thurberia weevil and the boll weevil complex can be controlled with proper sanitation measures applied to the crop residues, particularly preventing the growth of stubbed cotton. Thus although bioclimatic controls are generally adequate to minimize damage to cotton by boll weevils in Arizona, the grower may further minimize the damage with proper cultural practices.

258. ; Patana, R.; and McAda, W. C. 1969. Developmental periods for boll weevils reared at several constant and fluctuating temperatures. J. Econ. Entomol. 62: 1402-1405.

Developmental periods of 5 strains of Anthonomus grandis Boheman from cultivated cotton reanged from 88 days at 15°C to 17 days at 30°C; a temperature of 35°C increased the period to 17.5 days. Developmental periods of 1 strain of thurberia weevils, A. grandis thurberiae Pierce, ranged from 72.5 days at 15°C to 17.5 days at 30°C; a temperature of 35°C extended the developmental period of the weevils to 18.5 days. Temperatures above an undetermined temperature between 30° and 35°C prolonged the developmental period of all strains. The deleterious effect of high temperatures partially explains the absence of boll weevil populations in Arizona in

midsummer. Rearing at fluctuating temperatures did not increase the time required for development over that required at the constant temperatures if the heat input was similar and temperatures did not exceed 30°C.

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259. Ganyard, M. C., Jr.; Bradley, J. R., Jr.; Boyd, F. J.; and Brazzel, J. R. 1977. Field evaluation of diflubenzuron (Dimilin) for control of boll weevil reproduction. J. Econ. Entomol. 70: 347-350.

Diflubenzuron [Dimilin®; 1-(4 chlorophenyl)-3-(2, 6-difluorobenzoyl) -urea] was tested for control of Anthonomus grandis Boheman in a replicated field experiment. Test plots were located in an area isolated from commercial cotton by 19-40 km. A population density of ca. 250 overwintered boll weevils/acre (618/ha) was introduced into each of 15 plots. Three rates tested were 2-, 4-, and 8-oz AI/acre (141, 282, and 564 g/ha). Boll weevil damaged squares were collected from cotton plants weekly, incubated for 7-9 days, and examined for developing boll weevil larvae or pupae. Results showed that reproduction in the diflubenzuron treated plots was reduced by >99% over the check plots through the F_2 generation.

260. ; Bradley, J. R., Jr.; and Brazzel, J. R. 1978. Wide-area field test of diflubenzuron for control of an indigenous boll weevil population. J. Econ. Entomol. 71: 785-788.

Diflubenzuron (Dimilin®; 1-(4 chlorophenyl)-3(2, 6-difluorobenzoyl) -urea), was applied 9-10 times at 0.14 kg AI/ha to all 76 cotton fields in an isolated cotton production area for control of an indigenous low to moderate population of Anthonomus grandis grandis Boheman. Boll weevil population dynamics were recorded in the diflubenzuron treated fields and in a conventionally treated check area. Results indicated >90% control of reproduction. The F_3 boll

weevil population in the diflubenzuron treated area was no higher than the initial overwintered population, but the population increased 12X where conventional chemicals were used.

261. , and Brazzel, J. R. 1967. Phosphate insecticides and defoliants applied singly and in combination for control of boll weevils. J. Econ. Entomol. 60: 1027-1029.

An experiment was conducted on a laboratory-reared, nondiapausing, susceptible strain of boll weevils, Anthonomus grandis Boheman, to determine if certain phosphate insecticides and defoliants were compatible when combined and applied simultaneously. It was found that neither Def® (S,S,S-tributyl phosphorotrithioate) nor Folex® (tributyl phosphorotrithioate) inhibited the lethal potential of methyl parathion, malathion, or azinphsomethyl. In fact, the presence of a defoliant in mixture with an insecticide actually produced a slight additive effect on the lethal potential.

262. Gassner, G., III; Childress, D., and Klemetson, D. J. 1975. Spermiogenesis in boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae). Int. J. Insect Morphol. Embryol. 4: 115-125.

Spermiogenesis of Anthonomus grandis Boheman, the cotton boll weevil, was studied by transmission electron microscopy. The basic morphologic features investigated and illustrated were: acrosome, nucleus, fibrous masses, microtubules, and mitochondrial derivatives. A centriole adjunct was observed to surround the basal body (centriole derivative) early in spermiogenesis, but it subsequently disappeared. In the sperm tail, one mitochondrial derivative developed into a rod-like structure that inserted into a concavity at the base of the nucleus and terminated near the end of the tail. This mitochondrial derivative may provide a rigid base for the undulating membrane. In addition, the attachment of the rod to the nucleus may serve in a manner analogous to

the function that has been suggested for the centriole adjunct: it may anchor the head to the tail. A possible abnormal condition may arise when the mitochondrial derivative rod fails to insert into the sperm nucleus.

263. ; Childress, D.; Pomonis, G.; and Eaton, J. 1974. Boll weevil chemosterilization by hypobarometric distillation. J. Econ. Entomol. 67: 278-280.

Hypobarometric distillation appears to be a promising technique for sterilizing Anthonomus grandis Boheman because of the short exposure times. Boll weevils were exposed to hempa and hempa + isopropyl methane sulfonate for times ranging from 1-6 min. Males were effectively sterilized by the 2, 4, and 6 min treatments, although some recovery of fertility was evident in the 2nd and 3rd weeks posttreatment. Egg production by treated females was significantly decreased and egg hatch averaged 31%.

264. Gast, R. T. 1966. Control of four diseases of laboratory-reared boll weevils. J. Econ. Entomol. 59: 793-797.

Four diseases of the boll weevil, Anthonomus grandis Boheman, have interfered with the mass rearing of th sect at the Boll Weevil Research Laboratory. Two were caused by protozoans, one by bacteria, and one by an unidentified agent. These are the first known naturally occurring diseases of the boll weevil. Therapeutic control of 3 of the diseases has not been possible. The bacterium has been controlled by soaking the eggs in 0.8% formaldehyde.

265. . 1966. Oviposition and fecundity of boll weevils in mass-rearing laboratory cultures. J. Econ. Entomol. 59: 173-176.

By using new techniques and complete mechanization to mass produce eggs of the boll weevil, Anthonomus grandis Boheman, more than 1 million eggs per week were obtained at a cost of less than 10 cents per thousand. Of 9 diets tested, 2 containing soybean protein were most satisfactory. Diets,

formulated into pellets that also served as oviposition sites, were placed in wire baskets raised 3/16 inch above a screen-bottomed rearing cage designed with solid top and sides so that all light came from below the cage.

266. . . 1966. A spray technique for implanting boll weevil eggs on artificial diets. J. Econ. Entomol. 59: 239-240.

The container was filled with the implanting solution, sealed, and the compressed gas adjusted to 12 psi. Then an open petri dish containing larval media was held 3 in. below the spray nozzle and the pinch cock was opened to allow approximately 1 ml of implanting solution to spray on the larval media with this equipment, one technician can implant 300,000 eggs/hr in petri dishes. Since less injury to the eggs and embryo occurred, the spray method increased yields.

267. , and Davich, T. B. 1966. Boll weevils. In Carroll N. Smith (ed.), Insect Colonization and Mass Production, pp. 405-418. Academic Press, New York.

The boll weevil, Anthonomus grandis Boheman, has been a major pest of cotton for nearly half a century. Studies on this insect were limited to field-reared weevils until 1957, when Vanderzant and Davich (1959) first developed an artificial larval diet. Since then, progress in laboratory rearing of the boll weevil has reached a point where it is possible to produce the millions of weevils needed for a sterile male release eradication program if and when such a program becomes feasible. Mass production methos must be mechanized and often are not suitable for small cultures or for specific experiments, especially when it is desirable to obtain the highest possible yield of adults from a given number of eggs. It is possible to obtain yields of 75 to 80% by use of hand methods, while with efficient mechanical methods yields may be as low as 10 to 15%. The cost of rearing weevils by hand methods, however, may be over

$120.00 per thousand weevils while that of mechanical methods may be as low as $3.00 per thousand. Both types of rearing methods are necessary for studies of the boll weevil and both methods will be described in this chapter.

268. , and Landin, M. 1966. Adult boll weevils and eggs marked with dye fed in larval diet. J. Econ. Entomol. 59: 474-475.

In a study at this laboratory, more than 60 dyes were incorporated into the medium at 100 and 1000 ppm and fed to larvae of the boll weevil, Anthonomus grandis Boheman. Adults that showed any trace of color at eclosion were held until the color disappeared. The following dyes imparted color to the weevils but were excreted in the feces within 3 days after eclosion:

Dye	Coloration
4-Dimethylamino-4-methylazobenzene	Yellow adults
Fast Green	Pale green pupae, colorless adults
Nile Blue	Deep blue adults
Neutral Red	Deep red adults
Acridine Orange	Pale yellow adults
Toluidine Blue O	Pale blue adults
Calcozine Navy Blue MB®	Deep blue adults
Calcozine Green®	Pale green adults
Methylene Blue	Pale blue adults
Spirit Soluble Fast Violet®	Pale lavender adults
Spirit Soluble Fast Red®	Light pink larvae and pupae, colorless adults
Spirit Soluble Fast Black®	Lavender adults

269. Gemrich, E. G., II; Lee, B. L.; Nelson, S. J.; and Rizzo, V. L. 1978. Insecticidal aminothio derivatives of the pesticidal carbamate methomyl. J. Agric. Food Chem. 26: 391-395.

The insecticidal activities of a series of aminothio derivatives of methomyl were investigated. In general, the spectrum of activity of the compounds closely paralleled that of the parent, methomyl, often being equitoxic to the southern armyworm (Spodoptera eridania Cramer), cabbage looper (Trichoplusia

ni Hübner), cotton bollworm (Heliothis zea Boddie), tobacco budworm (Heliothis virescens Fabricius), and boll weevil (Anthonomus grandis Boheman) but less active against the house fly (Musca domestica L.) and house cricket (Acheta domesticus L.). Additional biological parameters of a single compound, U-46,855, methyl [[[methyl-(4-morpholinothio)amino]carbonyl]oxy]ethanimidothioate, were compared to those of methomyl in the laboratory. U-46,855 demonstrated a marked increase in foliar residual life, lower mammalian toxicity, and greater crop selectivity while methomyl was much more resistant to mechanical loss due to rain. Evaluation of chemicals for the control of the bollworm complex in Alabama demonstrated that U-46,855 produced significantly higher cotton yields than methomyl.

270. Gilliland, F. R., Jr. 1972. Influence of simulated early-season insect damage on growth and yield of cotton. Ala. Agric. Exp. Stn. Bull. 442, 11 pp.

The results of this experiment may well give cause for some reassessment of the importance of certain early-season insect infestations. Obviously, the cotton plants have the capacity to replace all of the squares lost to early-season attack from such insects as plant bugs and boll weevil. However, the indication that some early-season loss of squares to insect injury might even be beneficial must be considered with caution. Adverse climatic conditions during the period following the loss of early-season squares could seriously inhibit capacity of cotton plants to compensate for the square loss. Also, in the event of an early onset of cold weather in the fall, a delay in the boll maturity, caused by the loss of early-season squares, might have a disastrous effect on yields. One must also consider the impact of providing an abundance of late season squares and developing bolls as food for the diapausing generation of the boll weevil

and bollworm, Heliothis spp., during September and October. These considerations, however, should not obscure the important point that can be made from the results of this experiment. That is, heavy infestations of square-feeding insects during the early part of the season (prior to the third week of squaring) should not necessarily be of great immediate concern.

271. . 1972. A large scale boll weevil suppression experiment. Folia Entomol. Mex. 23-24: 19. (In Spanish).

A large scale boll weevil suppression experiment was conducted in 1969-1970 on 12,000 acres of cotton in Alabama. Diapause control, grandlure-baited wing traps, sterile insect releases, and a resistant variety of cotton were the control methods employed. Results will be discussed.

272. . 1974. Traps and trap crops for boll weevil suppression. Proc. 1974 Beltwide Cotton Prod. Res. Conf., pp. 128-130.

In general, this experiment confirmed results obtained in a similar experiment conducted in 1972. That is, trap crops offer considerable potential as a boll weevil suppression technique. However, the primary problem of implementation of the trap crop technique is the difficulty of planting trap crops at least two weeks before the regularly-planted portion of the field. Most producers are reluctant to delay their planting operation in this manner. However, the data indicate that the trap crops should be planted early if optimum results are to be achieved. Hopefully, additional research will produce methods of negating this difficulty.

273. , and Davich, T. B. 1966. Effects on egg hatch of alternate matings of female boll weevils with apholate-treated and untreated males. J. Econ. Entomol. 59: 1209-1211.

Virgin female boll weevils, Anthonomus grandis Boheman, were mated alternately in various sequences to untreated males and to males sterilized with apholate.

Results showed that when an equal number of matings with sterile and normal males occurred, both equally influenced overall egg hatch. The initial mating in the sequence had little effect on overall egg hatch, while the last mating prior to oviposition was most influential on subsequent egg viability. Only slight differences were noted between egg fertility from single and double matings, an indication that little additional sperm is transferred in the 2nd mating if it occurs within a few hours. The unlikely chance that numerous normal matings would occur during a sterile-male-release program when an overwhelming number of sterile males is present and the low percentage of viable eggs that actually develop into adults from combined matings with normal and sterile males should negate any adverse effects of alternate matings on the program.

274. , and Davich, T. B. 1968. Influence of population density on mating behavior of chemosterilized, untreated or overwintered boll weevils, Anthonomus grandis. Ann. Entomol. Soc. Am. 61: 834-836.

Untreated Anthonomus grandis Boheman females, paired with untreated males, mated significantly more than did untreated females paired with males treated with apholate, or overwintered females paired with overwintered males. With 1 exception, the number of mean matings for each combination housed in each of 3 different sized mating chambers was significantly different from that in the 2 other mating chambers housing the same combination. As the size of the mating chamber was increased, simulating a decrease in population density, matings of all combinations of weevils decreased.

275. , and Davich, T. B. 1968. Sexual competitiveness of male boll weevils sterilized with apholate unaffected by diet. J. Econ. Entomol. 61: 852-853.

Sexual competitiveness is a basic consideration for a sterile-male-release

program for the control and/or eradication of an insect species such as the boll weevil, Anthonomus grandis Boheman. In earlier reports, male boll weevils sterilized with apholate had a significant loss of vigor, and apholate-treated male weevils mated less frequently than untreated males when they were paired individually. This lack of sexual vigor could be caused by the sterilization and also, perhaps, by the rearing diet of the weevils. However, the only practical way to obtain the large number of weevils necessary for a sterile-male-release program is to rear them on this artificial diet; that is, weevils reared on artificial diet would have to compete with square- (flower bud) reared weevils during an eradication program. We therefore designed laboratory tests to compare the sexual competitiveness of square-reared and medium-reared chemosterilized males with that of similar groups of untreated males.

276. ; Lambert, W. R.; and Davis, R. L. 1976. Evaluation of a trap crop system for boll weevil suppression. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 90-94.

In general, this experiment confirmed results obtained in a similar experiment conducted in 1972. That is, trap crops offer considerable potential as a boll weevil suppression technique. The primary problem of implementing the trap crop system tested is the difficulty of successsfully planting trap crops at least 2 weeks before the remainder of the field. Most producers are reluctant to delay their planting operation in this manner. However, the data indicate that the trap crops should be planted much earlier than the regular crop if optimum results are to be achieved. In a well controlled and organized suppression program, eradication program or both, it may be possible to accomplish the necessary differential in planting of trap crops probably will in-

hibit wide acceptance and usage of a trap-crop system by individual growers. Hopefully, additional research may produce methods of trap cropping that will negate the necessity of early planting. For example, it may be possible to create a trap crop in a regularly planted portion of a field by the efficient use of grandlure bait stations alone. These baited portions could be treated with systemic or foliar-applied insecticides to kill weevils attracted by the grandlure.

277. ; Lambert, W. R.; Weeks, J. R.; and Davis, R. L. 1973. A pest management system for cotton insect pest suppression. Ala. Agric. Exp. Stn. Prog. Rep. Ser. 105, 5 pp.

In summary, the aldicarb-treated, early planted trap crop system was very effective in attracting and concentrating early-season boll weevil and bollworm populations in cotton. Damaging infestations of these pests were not sustained in the regular crop throughout the test period. Although further research is needed to clarify the role of each o f the insect suppression factors involved in the experiment, and while improvements must be made in mid-season suppression of Heliothis, it seems obvious from these studies that the pest management system tested has great potential for cotton insect pest suppression.

278. ; Lambert, W. R.; Weeks, J. R.; and Davis, R. L. 1976. Trap crops for boll weevil control. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 41-44.

It is apparent from these data that trap crops were an effective means of concentrating and suppressing emerging boll weevil populations if the trap crops were planted earlier than the main crop, and if pheromone bait stations were used.

279. , and McCoy, C. E. 1969. The behavior of newly emerged boll weevils. Ann. Entomol. Soc. Am. 62: 602-605.

Boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae), activity was recorded for a 48-hour period following emergence in greenhouse studies and from a few hours to 4 days following emergence in field studies. Weevils were observed to be active for a short time immediately after release, followed by a quiescent period lasting up to 2 hours. During the initial period of activity many weevils attained a host plant. Half the weevils in the greenhouse study and all the individuals in the field study had attained a plant within 4 hours after release. Morning-emerged weevils usually required less time to attain a host plant than did afternoon-emerged weevils. Plant attainment was almost always by crawling, and only a few weevils flew from the soil to a host plant. Leaves were the site of initial feeding by most of the weevils observed. In the greenhouse study an average time of 16.8 hours elapsed from release until initial feeding. Those weevils feeding initially on leaves were deterred for a considerable time in the location of and feeding upon a fruiting structure. However, this behavior was not observed in the field.

280. , and Rummel, D. R. 1978. The role of pheromone for boll weevil detection and suppression. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 84-95.

The discovery, isolation, and identification of the male-produced boll weevil aggregation pheromone and the subsequent synthesis and commerical availability of grandlure, the synthetic pheromone, has prompted both considerable speculation and research concerning the role of the pheromone phenomenon in boll weevil behavior, detection, and population management. A large amount of money and other resources has been expended to develop grandlure and the associated trapping technology to its present state. An

estimated $1 million was spent on the research program for isolation, identification, and laboratory synthesis of the pheromone. No estimate of subsequent expenditures by the various research stations involved in additional research is available, but certainly the sum is appreciable. It is generally agreed that grandlure-baited traps are an excellent means of boll weevil population detection and survey. Conversely, there does not seem to be a concensus concerning the role of grandlure in boll weevil population management. While success has been achieved in certain suppression experiments, the general inconsistency of experimental results and the lack of definite guidelines for population management strategies has precluded widespread acceptance of grandlure as a useful population management tool. It must be noted that the study of insect pheromones, particularly as regards the boll weevil, is still a relatively young science. It is probable that continued commitment to further research and development of pheromone technology and its implications for pest population suppression will provide worthwhile benefits to American cotton producers in the future.

281. Glick, B., and Mitlin, N. 1968. An immunological study of the antigens of Anthonomus grandis grandis and Anthonomus grandis thurberiae. Ann. Entomol. Soc. Am. 61: 548-550.

Homogenates from boll weevil and thurberia weevil revealed the presence of 3 antigens. Boll weevil and thurberia weevil Ag-a, closest to antisera well, and Ag-c, farthest from antisera well, exhibited patterns of fusion, and, therefore, are similar antigens. The center band, Ag-b, present in the boll weevil and thurberia weevil, failed to show a pattern of fusion. Therefore, the double-diffusion experiments suggest that there are immunological differences between the boll weevil and thurberia weevil. The slight immunological differences between the eastern boll weevil and the thurberia weevil should help in the taxonomic separation of these 2 weevils.

282. Graham, H. M.; Hernandez, N. S., Jr.; Llanes, J. R.; and Tamayo, J. A. 1978. Overwintering habitats of the boll weevil in the Lower Rio Grande Valley, Texas. Environ. Entomol. 7: 345-348.

Three yr of sampling for overwintering boll weevils, Anthonomus grandis Boheman, in debris from habitats adjacent to cotton fields near Brownsville, TX showed a density ranking of habitats, in descending order, of hackberry trees (Celtis laevigata Willd.), granjeno bushes (C. pallida Torr.), and open grassy areas. However, more total weevils were found in grassy areas, which were the most abundant of the habitats. Populations of overwintering weevils were lowest the winter after the cotton crop had been harvested and plowed under by Aug. 31.

283. ; Hernandez, N. S., Jr.; Llanes, J. R.; and Tamayo, J. A. 1979. Seasonal incidence of diapause in boll weevil populations in the Lower Rio Grande Valley of Texas. Southwest. Entomol. 4: 170-175.

The first diapausing boll weevils, Anthonomus grandis Boheman, were collected from cotton plants in the lower Rio Grande Valley of Texas in mid- to late-June, about the time the first open bolls appeared. The proportion of diapausing weevils increased rapidly during July as the plants matured and then were defoliated. Estimated total populations of boll weevils and estimated populations of diapausing weevils were greatest during a year when frequent rains hampered insecticide application, harvest, and destruction of crop residue.

284. ; Wolfenbarger, D. A.; and Nosky, J. B. 1978. Labeling plants and their insect fauna with rubidium. Environ. Entomol. 7: 379-383.

Single applications of aqueous sprays of rubidium chloride (RbCl) were made at rates of 0.625-10 kg/ha to cotton, grain sorghum, and hyacinth bean, Dolichos lab-lab L., to label the plants and insects on them with elevated levels of Rb. However, at all rates tested there was overlapping of the concentration of Rb in

insects collected from treated plants with the Rb content of those from untreated plants. Some entomophagous insect species were labeled with Rb, indicating the Rb moved through the food chain from producers through primary to secondary consumers.

285. Graves, J. B.; Earle, N. W.; Bradley, J. R., Jr.; and Clower D. F. 1969. Field studies of an attractant in the male boll weevil. La. Agric. 12(3): 14-15.

Data from this study indicated that male boll weevils do emit an attractant(s) to which both sexes of its species respond under certain conditions in the field. The greatest response is obtained early in the season prior to plant fruiting and late in the season when field weevils are being exposed to diapause-inducing conditions. The attractant(s) would appear to be very useful in survey and detection of boll weevils and may well aid in their control.

286. ; Roussel, J. S.; Gibbens, J.; and Patton, D. 1967. Laboratory studies on the development of resistance and cross-resistance in the boll weevil. J. Econ. Entomol. 60: 47-50.

Laboratory experiments were undertaken to determine if resistance could be developed in the boll weevil, Anthonomus grandis Boheman, to a representative chemical in each of 3 classes of insecticides now being used for its control. The topical-application technique and insecticide-contaminated larval media were the 2 methods of selection utilized. Selections for resistance to azinphosmethyl and carbaryl, using the contaminated larval media, were unsuccessful. However, selections for resistance utilizing the topical application of the selective insecticides were successful in the cases of endrin and a 2:1 mixture of toxaphene-DDT. Where endrin was used as the selective agent in 1 generation and azinphosmethyl in the next generation for 27 generations, resistance was

developed to endrin but not to azinphosmethyl. The most important finding was that the laboratory-developed toxaphene-DDT-resistant culture exhibited cross-resistance to 3 organophosphates (5- to 12-fold) and 2 carbamates (40-fold or greater). Two endrin-resistant cultures exhibited lower levels of cross-resistance to these same materials.

287. Griffin, J. G. 1978. A system for the egg planting operation in boll weevil mass rearing. Trans. ASAE 21: 469-472.

Equipment consisting of an in-line form-fill machine; a semi-automatic liquid filter; a refrigerated cooling unit; a weevil egg planting unit, and a grandular material filler were developed and/or modified and installed into a system to mechanize the egg planting operation in boll weevil mass rearing. The size of the system developed was capable of producing, filling and planting approximately 700 tray units per hour which with normal yeild should produce approximately 250,000 adult weevils. The system required about 11 percent as much hand labor as the previous planting operation and most of this labor was utilized in stacking the planted tray units.

288. . 1979. Actuator system for operating small ball valves. U.S. Sci. Educ. Adm. Adv. Agric. Technol. South. Ser. (ISSN 0193-3728), No. 2, 4 pp.

The system consists of two-way ball valves; a liquid manifold; an air-valve manifold with four-way, electrically operated air valves; double-acting air cylinders; and a recycling timer-switch unit. The parts are mounted on a metal frame. The system was developed for use in the manufacture of food pellets for boll weevils but could be adapted to operations requiring one or more flow-control valves to be operated in sequence or all at once.

289. . 1979. Egg planter for a boll weevil mass-rearing operation. U.S. Sci. Educ. Adm. Adv. Agric. Technol. South. Ser. (ISSN 0193-3728), No. 6, 5 pp.

Equipment used in a mass-rearing operation to plant boll weevil eggs must aseptically handle, accurately meter, and uniformly disperse the eggs on the surface of the congealed larval rearing medium. The egg planter described is part of a mechanized in-line operation and consists of several components, including a filler to meter and a spray nozzle to disperse the eggs on the surface of the medium. The equipment is capable of planting boll weevil eggs at the capacity of the production line, 14 to 15 trays per minute, or about 2 to 2 1/4 million egg per hour. Only the minor task of changing the holding jars containing the egg suspension is still performed manually.

290. . 1979. Equipment for cooling larval diet in a boll weevil mass-rearing operation. U.S. Sci. Educ. Adm. Adv. Agric. Technol. South. Ser. (ISSN 0193-3728), No. 1, 3 pp.

In the mechanized in-line operation used to plant boll weevil eggs, sterile larval diet must be cooled after being dispensed into rearing trays so that it is solid enough to support the eggs that are placed on the diet surface. The cooling system consists of a refrigerated tunnel through which the trays of warm diet pass and into which cold, filtered air is blown. The equipment is capable of cooling the trays of diet at the capacity of the production line (14 trays per minute) and helps to prevent microbial contamination of the diet.

291. . 1979. "Rackveyor" for use in mass rearing of boll weevils. U.S. Sci. Educ. Adm. Adv. Agric. Technol. South. Ser. (ISSN 0193-3728), No. 4, 3 pp.

The trays of larval diet and eggs in a boll weevil mass-rearing operation must be maintained in the proper environment while being conveyed from place to

place. The equipment described provides a place to stack the trays, allows a satisfactory environment to surround the stacked trays (provided a proper environment is maintained in the holding rooms), and provides means for conveying the trays from one location to another. The unit saves time and labor and provides a more satisfactory microenvironment around the trays than previously used equipment.

292. , and Lindig, O. H. 1973. Ultraviolet lamp pass-through cabinet for use in boll weevil mass-rearing facility. J. Econ. Entomol. 66: 1063-1066.

A two-door, ultraviolet (UV) or germicidal lamp pass-through cabinet and control system were developed for use in an Anthonomus grandis Boheman mass-rearing facility. The unit allows passage of materials between rooms, or between rooms and the outside, with better contamination control than is possible by using ordinary doorway passages. Tests showed that microbial organisms which were suspended in air or spread in thin layers on filter paper were destroyed when exposed to the radiation produced by the lamps in the unit. The control system was designed and installed so that only one door of the cabinet could be opened at one time. When either door was opened and then closed, both doors were locked and the UV lamps were activated and remained on for a preset length of time before either door could be opened. The UV lamps could not be operative when either door was open. Lamp fixtures were mounted in the cabinet so that any packages or containers placed in the cabinet were surrounded by germicidal lamp rays.

293. , and Lindig, O. H. 1974. Mechanized production of boll weevil diet pellets. Trans. ASAE 17: 15-16, 19.

The size of equipment developed was capable of producing 150,000 or more pellets per man hr of operation, whereas the equipment and the method that are presently used required 6 to 8 man hr of labor to produce this number

of pellets. With the present rearing and sterilizing methods, the new equipment provided a saving of ca. 18 man hr of labor per day for making the adult diet pellets needed for each 1 million sterile male weevils produced per week and the labor saved would be greater if both sexes of weevils were fed the pellets containing the chemosterilant.

294. , and Lindig, O. H. 1975. Granular materials used in implanting boll weevil eggs on artificial diet. J. Econ. Entomol. 68: 433-434.

Granular materials were used to cover the artificial diet and the eggs of Anthonomus grandis Boheman after the eggs were sprayed on the diet surface as a substitute for the usual diet scarifying and drying operation. The number of adult weevils produced from the petri dishes when the diet and eggs were covered with mortar sand, vermiculite, fine mineral granules, and corcob grit was as great as or greater than that produced from the regular egg implanting method. By use of the granular material covering, the scarifying and drying operations of the regular egg planting method can be eliminated.

295. , and Lindig, O. H. 1977. System for mechanical harvesting of boll weevil eggs from diet pellets. Trans. ASAE 20: 454-456.

The equipment designed, constructed and tested and the operational techniques used in evaluating the equipment and systems were satisfactory for harvesting boll weevils eggs for food pellets commonly used for laboratory reared weevils. The equipment and system provides for harvesting large volumes of weevil eggs with low man hours of labor without reducing the hatch of eggs.

296. , and Lindig, O. H. 1979. Emergence cabinet for mass rearing of boll weevils. U.S. Sci. Educ. Adm. Adv. Agric. Technol. South. Ser. (ISSN 0193-3728), No. 10, 6 pp.

The cabinet holds trays of rearing medium during the emergence period. Newly emerged boll weevils are attracted by light into attached collecting cages.

The cabinet accommodates 920 trays that normally produce 450,000 or more adult weevils. One person can handle the cabinet and collect the adults from the cage.

297. , and Lindig. O. H. 1979. Oviposition cage and auxiliary equipment for mass rearing of boll weevils. U.S. Sci. Educ. Adm. Adv. Agric. Technol. South. Ser. (ISSN 0193-3728), No. 5, 5 pp.

Equipment was developed to reduce the time and labor required to handle and feed the large numbers of boll weevils used for egg production in a mass-rearing operation. The equipment, all of which can be handled by one person, consists of large oviposition cages, which accommodate 9,000 adult weevils each, a cage shaker, and a cage conveyor. The shaker simplifies changing the food pellets daily, and the conveyor holds and moves up to 150 oviposition cages at a time. One person can feed a cage of weevils in about 1 minute with the equipment.

298. ; Lindig, O. H.; and McLaughlin, R. E. 1974. Flash sterilizers: sterilizing artificial diets for insects. J. Econ. Entomol. 67: 689.

Extensive use of the shell and tube sterilizer in the Gast Rearing Laboratory, Mississippi State, Miss., has subsequently proved that it will satisfactorily sterilize and handle the artificial diets for boll weevils when operated properly. An automatically operated temperature controller and valve, Barber-Coleman Models 532 and MP 481, were added to the units to control the sterilizing and cooling temperatures during actual operation. These additions eliminated the time and labor necessary for manual regulation to maintain desired temperatures.

299. ; Lindig, O. H.; Roberson, J.; and Sikorowski, P. 1979. System for mass rearing boll weevil in a laboratory. Miss. Agric. For. Exp. Stn. Tech. Bull. 95, 15 pp.

The system described was tested for six weeks in 1976 and for eight weeks in 1977.

The production rate of about 5,058,000 weevils per week in 1976 increased to 6,243,000 weevils per week in 1977, after antimicrobial agents were added to the sand. Fewer than 1% of the trays had microbial contamination in the 1977 tests. Our results are conclusive that large numbers of boll weevils can be reared in the laboratory with currently available equipment and technology.

300. , and Roberson, J. 1980. New and improved techniques for mass rearing boll weevils. Southwest. Entomol. 5: 165-168.

A new system was developed for handling rearing trays for planting through adult emergence of mass reared boll weevils, Anthonomus grandis grandis Boheman. Use of the new system resulted in reducec cost for equipment, and considerable savings in time and labor for handling and allowed for fumigation of each development and emergence unit after each production cycle. Experimental results indicated that the yield of adult weevils with the new system was equal and possibly superior to that obtained with the standard system.

301. ; Roberson, J.; and Malone, O. L. 1980. Boll weevil development in mass rearing: Effects of temperature. Environ. Entomol. 9: 72-74.

This study was made to determine whether a temperature could be found that would cause laboratory (mass) reared boll weevil, Anthonomus grandis grandis Boheman, to develop at an uniform rate (85% or more of insects pupated at the beginning of adult emergence) from eggs to adults in 11-12 days and to obtain an 85% or larger emergence of adults during a 3 day or less period but not have a decrease in yield of weevils. Three tests were conducted in which 7 developmental-period temperature regimens were used. When the rearing-medium temperature was held constant at 30.0°C for the entire development period (egg to adult stage), the total development period was 2 days shorter than with the other temperature regimens studied, but the yield of adults was lower than with some of the other

temperature regimens. None of the temperatures studied resulted in uniform insect development.

302. Grodner, M. L. 1975. Aberrant spermatogenesis in hybrid progeny of subspecies of the boll weevil Anthonomus grandis Boheman (Coleoptera: Curculionidae). Int. J. Insect Morphol. Embryol. 4: 107-114.

Reproductive isolation occurs between the boll weevil (Anthonomus grandis grandis and the thurberia weevil (Anthonomus grandis thurberiae). The F_1 hybrid males from crosses of some populations are unable to produce sperm which are capable of moving to the spermatheca of the female to which they are mated. Electron micrographs reveal a disrupted pattern of spermatogenesis which probably results in structurally abnormal sperm.

303. . 1979. Fine structure of the spermathecal gland of the cotton boll weevil, Anthonomus grandis, Coleoptera: Curculionidae. Int. J. Insect Morphol. Embryol. 8: 51-58.

The secretion of the spermathecal gland, an epidermal derivative, was suggested as the source of nutrients for the sperm which are stored in the spermatheca. This secretion is also necessary for spermathecal filling. The gland consists of 2 types of cells, secretory cells and collecting or ductule cells. The products of the secretory cells are deposited in a central cavity lined with microvilli. The collecting ductule extends into the central cavity and the secretory products move down the ductule into the central lumen of the gland. The contents of the gland are then deposited in the spermatheca. The ductules, ducts and the central lumen of the gland are lined with cuticle, as is the spermatheca. The secretion of the glands from weevils less than 24 h old apparently differs from those of 3 day old weevils.

304. , and Steffens, W. L. 1978. Evidence of a chemotactic substance in the spermathecal gland of the female boll weevil (Coleoptera: Curculionidae). Trans. Am. Microsc. Soc. 97: 116-120.

The male boll weevil deposits sperm in the copulatory pouch of the female during mating. Normally, the sperm swim up the spermathecal duct and enter the spermatheca where they are stored until they are used for fertilization. The sperm exhibit a positive chemotactic response to the secretion of the spermathecal gland. This is the first report of evidence of a chemotatic substance in the internal secretions of the reproductive tract of the female.

305. Gueldner, R. C.; Hedin, P. A.; and Woodard, D. N. 1975. Mineral content of boll weevils, cotton buds, and synthetic diets. J. Econ. Entomol. 68: 428-430.

The mineral content of Anthonomus grandis Boheman, wild and mass-reared, cotton buds and synthetic diets was determined by atomic absorption spectrophotometry. Manganese was low by a factor of 10 in the artificial diet when compared to cotton squares. All minerals except copper were enhanced, especially iron (100-fold) in overwintered weevils when compared to F_1 weevils.

306. ; Sikorowski, P. P.; and Wyatt, J. M. 1977. Bacterial load and pheromone production in the boll weevil, Anthonomus grandis. J. Invertebr. Pathol. 29: 397-398.

The boll weevil, a major pest of cotton, is the target of a proposed large-scale eradication program that is to include the release of large numbers of sterile males. These male boll weevils must be mass-reared, and the mass-reared insects must be competitive with native weevils in the field. Unfortunately, mass-reared boll weevils are sometimes not competitive because they are less vigorous than wild ones, a condition that has been attributed to bacterial con-

tamination of the weevils during the rearing process. Results of our tests showed that more pheromone was always isolated from the frass of uncontaminated weevils, by a factor of 1.2-300. The results were significant at the 1% level of probability (P=0.01). The quality of weevils that are contaminated with bacteria is therefore reduced from that of normal weevils insofar as pheromone production is concerned.

307. ; Thompson, A. C.; Hardee, D. D.; and Hedin, P. A. 1970. Constituents of the cotton bud. XIX. Attractancy to the boll weevil of the terpenoids and related plant constituents. J. Econ. Entomol. 63: 1819-1821.

Bioassay results with 37 terpenoids and related plant constituents indicate that linolool oxide, geranyl acetate, neryl acetate, rose oxide, fenchone, menthone, isovaleraldehyde, and linalool were among the most attractive to Anthonomus grandis Boheman. Three 4-6 component mixtures were nearly as attractive as extracts of cotton buds.

308. , and Wiygul, G. 1978. Rhythms in pheromone production of the male boll weevil. Science 199: 954-986.

Male boll weevils, Anthonomus grandis, held in a light regimen of 16 hours of light and 8 hours of darkness released pheromone rhythmically during the 24 hours. The amount released during peaks was typically 20 times the amount released in valleys. The ratio of the two alcohol components of the pheromone also showed a daily rhythm. Under continuous light, both the release of pheromone and the ratio of the two alcohol components were arrhythmic. In darkness, pheromone release was diminished more than tenfold over the 20-day test period.

309. Guerra, A. A.; Garcia, R. D.; and Wolfenbarger, D. A. 1980. Activity of 3 cyclohexadiene analogs against the boll weevil, Anthonomus grandis, and tobacco budworm, Heliothis virescens. Southwest. Entomol. 5: 153-157.

Three analogs of cyclohexadiene I) 2,6-dibromo-4-hydroxy-4-methyl-2, 5-cyclohexadiene-1-one; (II) 2, 6-dibromo-4, 4-dimethyl-2, 5-cyclohexadiene-1-one; and (III) 2, 6-dibromo-4-hydroxy-4-methyl-2, 5-cyclohexadiene-1-one acetate were tested for activity against the boll weevil, A. grandis Boheman, and the tobacco budworm, H. virescens (F.). Only compound III was effective against the boll weevil, but all 3 compounds showed activity against the tobacco budworm. Spray applications of compound III on cotton in the field caused reduction in the development of boll weevils in cotton squares and, when incorporated into artificial larval diet, the chemical reduced adult emergence apprx. 90% at concentrations as low as 0.001% (wt/vol). Applications of compound III as a foliar spray to potted cotton plants completely inhibited the hatch of tobacco budworm eggs. Topical applications of the chemical were effective against 1st stage tobacco budworms. Topical applications of compound I significantly affected larval development, pupation and adult eclosion of this insect in the laboratory.

310. Guice, O. T., Jr. 1976. Regulatory activities carried on under the Pilot Boll Weevil Eradication Experiment, 1971-73. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 73-74.

Results were most gratifying, and except for possibly less than one-half dozen cases involving relatively minor instances, quarantine and regulatory problems were fewer than in perhaps any quarantine program with which I have been associated in some 35 years in dealing with regulatory matters. In only one case did we have to go to the point of notifying a producer that an injunc-

tion would be served to prevent his interference with the program. This resulted largely from the fact that he did not fully understand the goals of the program, and after they were fully explained to him we did not have to ask the court to serve the injunction.

311. Gurrola, C. G. 1973. Advances in chemical control of the cotton weevil, Anthonomus grandis, in Iguala, Guerrero. Folia Entomol. Mex. 25-26: 73. (In Spanish).

In efficacy tests, the most effective insecticides against the cotton boll weevil were Thiodan + methyl parathion (30-15), Guthion (25%), Padan (50%) and Gus-Gus (200-200). Somewhat less effective were methyl parathion (50%) + malathion (96%) LV, PP 511 and Cytel 1000. The mixture of Endrin + methyl parathion were very toxic to man and warm blooded animals.

312. Gutierrez, A. P.; Wang, Y.; and Daxl, R. 1979. The interaction of cotton and boll weevil - A study of co-adaptation. Can. Entomol. 111:357-366.

The growth parameters for cotton (Gossypium hirsutum L.) were examined via optimization studies to determine if the observed values were optimal for the season lengths and weather patterns found in California and Nicaragua. The parameters observed for Nicaraguan cotton were further examined to determine if predation by boll weevil (Anthonomus grandis Boh.) of small cotton fruit (squares) could explain the observed discrepancies. All of the observed growth parameters except the fruit bud production rate for the Acala Sj II variety of cotton which is grown in California appeared to be reasonably optimal for California condition (i.e. boll weevil does not occur in California). By contrast, the parameters for the Nicaraguan variety were sub-optimal if boll weevils was exlcuded from the analysis, but near optimal if the population dynamics of pest were included.

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313. Hanna, R. L. 1975. Chemical control of cotton insects in the Brazos Valley of Texas. Folia Entomol. Mex. 33: 22. (In Spanish, abstract only).

Cotton is grown in widely different geographical areas in Texas. Much of the crop is produced in the northwestern plains area where most insects are suppressed by climatic factors. Problems in the Brazos river valley represent those of the alluvial valleys and the coastal plain and are common to many cotton production areas of the Mexican States. Needs for chemicals in the pest management program for cotton generally fall in one of two categories: those needed at low rates early in the season to limit damaging populations of insects such as thrips and fleahoppers that interfere with early growth and fruiting and those needed at higher rates to protect set fruit from insects such as Heliothis, boll weevil and pink bollworm. Integrative dosages of a number of insecticides have been determined for use in the first category. Boll weevil and bollworm control is still being accomplished in most cases by a number of organophosphorus compounds. Control of resistant strains of the tobacco budworm has been obtained only by the use of methomyl dust.

314. Hardee, D. D. 1970. Pheromone production by male boll weevils as affected by food and host factors. Contrib. Boyce Thompson Inst. 24(Oct./Dec.): 315-321.

An investigation of the influence of diet on production of pheromone by the boll weevil, Anthonomus grandis, revealed that: 1) laboratory-reared males were as attractive as native males if they had access to cotton squares (flower buds) as food; 2) males fed cotton squares, bolls and blooms were considerably more attractive than males fed terminals, cotyledons, and leaves; 3) pheromone production was reduced by about 50 percent 1 hour and over 90 percent 24 hours after food was removed; 4) males survived well and

produced pheromone on a variety of foods, such as apples, bananas, okra, peaches, and string beans, but the most favorable diet was cotton squares; and 5) overwintered male boll weevils survived longer without food than laboratory-reared males, but both needed some food before pheromone production began. These results indicate that a constant supply of adequate food, preferably cotton squares or small cotton bolls, is essential to continued production of pheromone by males.

315. . 1975. Boll weevil population management, detection or elimination with in-field traps. Proc. 1975 Beltwide Cotton Prod. Res. Conf., pp. 132-135.

We have known since 1969 that grandlure, the mixture of synthesized chemicals comprising the pheromone of the boll weevil, Anthonomus grandis Boheman, will elicit behavioral responses identical to those produced by the natural chemicals emitted by the male boll weevil. These responses include attraction to male and female boll weevils (aggregating pheromone) in early (overwintered) and late (migrating) season boll weevils, and attraction to females (true sex pheromone) in mid-season. When male-baited traps and trap crops were proved effective in 1968-71 in surveying and suppressing boll weevils, and when synthesized grandlure was proved effective in nature in 1969-70, grandlure was used widely in traps and trap crops by over 40 researchers in 1971-73 in 13 U.S. cotton-producing states and 5 foreign countries in survey and management of the boll weevil. In addition, grandlure in traps and trap crops played a key role in the Pilot Boll Weevil Eradication Experiment completed in 1973.

316. . 1976. Development of boll weevil trapping technology. In Boll Weevil Suppression, Management, and Elimination Technology. Proc. of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric.

Res. Serv. [Rep.] ARS-S-71, pp. 34-40.

These five trapping experiments illustrate that even with somewhat inefficient procedures, male-baited traps effectively removed a portion of overwintered boll weevils from a developing population and thereby provided a degree of suppression sufficient to justify inclusion of the trapping principle as one of the suppression measures in the PBWEE. Subsequent to these experiments several improvements made the trapping principle even more efficient.

317. . 1977. Managing and monitoring boll weevils and tobacco budworms with grandlure and virelure. Proc. 1977 Beltwide Cotton Prod.-Mech. Res. Conf., pp. 78-79.

One of the most promising new tools available to cotton farmers for reducing the heavy load of insecticide costs for several important pests on cotton is pheromones, chemicals produced by one sex of an insect to attract the same and/or opposite sex to the same area for purposes of mating. This manuscript discusses the commercial application and availability of grandlure and virelure, pheromones for the boll weevil, *Anthonomus grandis* Boheman, and the tobacco budworm moth, *Heliothis virescens* (F.), respectively.

318. , and Boyd, F. J. 1976. Trapping during the Pilot Boll Weevil Eradication Experiment, 1971-73. In Boll Weevil Suppression, Management and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 82-89.

One week after 1/3-grown square, with random sampling we had 8 chances in 100 of detecting, in any field, 1 egg-punctured square in a sample of 400, given the above assumptions. In any field of less than 10 acres the chances would be improved but where populations are less than two weevils per 10 acres, as the season progresses (and number of squares per acre increases),

the chances decrease drastically to approximately four in 1,000 at peak squaring. Based on these assumptions and calculations, the results as shown in tables 10-12 emphasize that in-field traps should be considered as one of the measures to be used in detection, management, suppression, and elimination of the boll weevil in any future programs.

319. ; Cleveland, T. C.; Davis, J. W.; and Cross, W. H. 1970. Attraction of boll weevils to cotton plants and to males fed on three diets. J. Econ. Entomol. 63: 990-991.

Previous investigations in the laboratory and in the field showed that male boll weevils, Anthonomus grandis Boheman, fed on cotton squares (flower buds) were more attractive than males fed on pellets of artificial medium, regardless of the strain of boll weevils. Presumably, this greater attraction occurred because the cotton squares contain a higher concentration of the materials necessary for the production of the pheromone by males. However, previous field tests of the male pheromone have been restricted to a comparison of the attraction of males held in screened boxes and fed pellets of medium or squares removed from growing cotton plants. Therefore, the presently reported tests were made in 1968 to compare the attraction of native boll weevils to laboratory-reared males (fed pellets of medium, fresh squares, or squaring cotton plants) with the attraction to squaring cotton alone in each of 3 areas: State College, Miss.; Tallulah, La.; and Waco Tex.

320. , and Cross, W. H. 1968. Trapping female boll weevils in a large cage at Iguala, Mexico, using male sex attractant. Folia Entomol. Mex. 18-19: 27. (In Spanish).

Laboratory-reared female boll weevils (Anthonomus grandis Boheman) were released at the Campo Experimental of the Instituto Nacional de Investigaciones Agricolas, Iguala, Mexico, in a 1/2-acre field cage divided into 8, 1/16-acre

sections and allowed to respond to the sex attractant emitted by live males or extracts of males in traps. A solid-wing, Stikem-coated trap and an oblique funnel trap were the most effective trap designs. Male extracts captured approximately one-half as many females as did males. Of 480 total females released, 163 were captured, an additional 77 females responded to within 45 inches of the traps, and 38 females responded or were captured more than once. Average daily mortality for the females was determined as about 20%, with a large population of spiders within the cage being considered the most important factor contributing to mortality.

321. ; Cross, W. H.; Huddleston, P. M.; and Davich, T. B. 1970. Survey and control of the boll weevil in west Texas with traps baited with males. J. Econ. Entomol. 63: 1044-1048.

Traps baited with live male Anthonomus grandis Boheman were effective for surveying populations of overwintered and migrating boll weevils, but in midseason, competition from males in fruiting cotton and decreased movement of weevils from field to field reduced the effectiveness. The larger catches observed in all areas from about Aug. 20 indicated that dispersal of weevils occurred at this time. Traps placed in and around a field of cotton in an area heavily infested with boll weevils captured > 4000 overwintered boll weevils per cotton acre but failed to reduce populations because the weevils in the traps could not compete with the large number of native weevils in the cotton. Traps placed in and around a field of cotton in an area with a small population of weevils (inside the Texas High Plains reproduction-diapause control zone) captured enough overwintered boll weevils to suppress the population until dispersal began. Thus, the pheromone of the male boll weevil is a potential tool for future survey, control, and eradication programs, but the population of overwintered weevils must be reduced

throughout a large area before the traps can prevent buildup of populations to damaging levels or accomplish eradication.

322. ; Cross, W. H.; and Mitchell, E. B. 1969. Male boll weevils are more attractive than cotton plants to boll weevils. J. Econ. Entomol. 62: 165-169.

The definite preference of overwintered and late-season Anthonomus grandis Boheman for male weevils compared with that for fruiting cotton suggests that the pest may be less attracted to weevil-free cotton than to cotton containing male weevils that have found the plant by random flight or because of a short-range response to a plant attractant. Traps baited with live male weevils or with a synthetic male pheromone may thus prove a possible new method of control and/or eradication of boll weevils and a valuable method of making surveys to detect small, incipient populations of boll weevils formerly not easily surveyed.

323. ; Cross, W. H.; Mitchell, E. B.; Huddleston, P. M.; and Mitchell, H. C. 1972. Capture of boll weevils in traps baited with males: Effect of size, color, location, and height above ground level. Environ. Entomol. 1: 162-166.

Optimum conditions were determined for capturing Anthonomus grandis Boheman in traps baited with males. Metal wing traps were painted daylight fluorescent yellow over a white undercoat (about 4 x 6-in. wings x 9-in. base) and were coated with an adhesive. Traps were baited with male boll weevils which were held in a container with a single layer of screen and placed at heights of 1-3 ft above ground around a cotton field adjacent to overwintering sites. This system, or a slight modification, would be useful in subsequent surveys and for control or possible eradication of the boll weevil with traps.

324. ; Cross, W. H.; Mitchell, E. B.; Huddleston, P. M.; Mitchell, H. C.; Merkl, M. E.; and Davich, T. B. 1969. Biological factors influencing responses of the female boll weevil to the male sex pheromone in field and large-cage tests. J. Econ. Entomol. 62: 161-165.

Results of studies of female Anthonomus grandis Boheman made to determine the influence of biological factors on its response to male sex pheromone indicated that: (1) laboratory-reared males were as attractive and females were as responsive as native weevils if they had access to cotton squares (flower buds) as food; (2) increased attraction of isolated males over grouped males was substantiated; (3) males in close proximity to females were no more attractive to females than isolated males; (4) the lack of response of recently mated females emphasized the need to capture females in traps before they mate with free, competing males; (5) sterilization of males with apholate or irradiation did not significantly decrease their attractiveness compared with untreated males; (6) females responded to males as many as 3 times and from distances of as much at 82 m; (7) the high percentage of females captured in traps baited with males in the absence of competing males, and the low percentage captured with males in traps in an infested plot containing large numbers of competing males suggest that the sex pheromone might have a major role in suppressing weevil populations in areas where populations are extremely low, for example, in the spring after an effective fall diapause-control program the substantially reduced the number of overwintering boll weevils.

325. , and Davich, T. B. 1966. A feeding deterrent for the boll weevil, Anthonomus grandis, from tung meal. J. Econ. Entomol. 59: 1267-1270.

A substance that deters feeding of the boll weevil, Anthonomus grandis Boheman, was found in the filtrate of a water extract of tung meal, a byproduct of the process of extracting oil from the seeds (nuts) of the tung tree. Aleurites

fordii Hemsl. The same substance (or a related substance) was present in more concentrated form in tung oil. The deterrent effect of the substance(s) was greater than that produced by a water extract of calyxes from buds of Rose-of-Sharon, Hibiscus syriacus L. The substance is readily soluble in water, resistant to moderate heat, and volatilizes slowly. A 2- to 15-fold decrease occurred in the number of feeding punctures made by boll weevils (compared with the controls) when cotton squares (buds) were dipped in a filtrate of water homogenized with tung meal that had been expeller-extracted. This deterrent effect was less when a filtrate of a homogenate of water and meal extracted by using hexane as a solvent was used and was greater when pure tung oil was used. In studies of serial dilution, the increase in deterrent effect was directly proportional to the increase in concentration of the filtrate. Antennectomy of boll weevils did not reduce the deterrent effect.

326. ; Graves, T. M.; McKibben, G. H.; Johnson, W. L.; Gueldner, R. C.; and Olsen, C. M. 1974. A slow-release formulation of grandlure, the synthetic pheromone of the boll weevil. J. Econ. Entomol. 67: 44-46.

An experimental slow-release formulation of grandlure, the synthesized pheromone of the male of Anthonomus grandis Boheman, proved to be 90-100% as effective in the field as male weevils when the weevils and the formulation were tested in the field for 7 days or longer. The formulation was superior to formulations used previously and was used effectively in traps for survey and research and in the Pilot Boll Weevil Eradication Experiment in S. Mississippi.

327. ; Lindig, O. H.; and Davich, T. B. 1971. Suppression of populations of boll weevils over a large area in west Texas with pheromone traps in 1969. J. Econ. Entomol. 64: 928-933.

Infestations were not found in 17 of 34 cotton fields in west Texas in which

wing traps baited with male Anthonomus grandis Boheman, were used. Moreover, adult weevils were found in only 7 of the 17 fields, and populations of boll weevils did not reach economically damaging levels in any of the fields. However, traps around all 34 field captured boll weevils in low to moderately high numbers. The traps suppressed more than 80% of the boll weevils, with traps placed around the fields in tiers, and used in conjunction with trap plots treated with aldicarb giving the best results.

328. ; McKibben, G. H.; Gueldner, R. C.; Mitchell, E. B.; Tumlinson, J. H.; and Cross, W. H. 1972. Boll weevils in nature respond to grandlure, a synthetic pheromone. J. Econ. Entomol. 65: 97-100.

Both sexes of Anthonomus grandis Boheman responded in the field to a synthetic pheromone mixture, grandlure. A wick-type formulation of grandlure containing glycerol, water, polyethylene glycol, and methanol was over 80% competitive as an attractant for 7 days with caged, live males fed cotton squares (flower buds) once or twice a week.

329. ; McKibben, G. H.; and Huddleston, P. M. 1975. Grandlure for boll weevils: Controlled release with a laminated plastic dispenser. J. Econ. Entomol. 68: 477-479.

A new system of dispensing grandlure, the synthetic pheromone of Anthonomus grandis Boheman, is composed of a 3-layer dispenser containing grandlure in the inner layer. The laminated dispenser was equal in effectiveness to currently used formulations and sometimes was attractive longer than 14 days.

330. ; McKibben, G. H.; Rummel, D. R.; Huddleston, P. M.; and Coppedge, J. R. 1974. Response of boll weevils to component ratios and doses of the pheromone, grandlure. Environ. Entomol. 3: 135-138.

Field tests of variations in concentrations of the 4 components of grandlure, the pheromone of the boll weevil, Anthonomus grandis Boheman, showed that in-

creased percentages of alcohols (and thereby decreased percentages of aldehydes) significantly improved performance. One alcohol was more important than the other in determining activity, but both alcohols must be present with small amounts of the aldehydes for maximum effectiveness. Captures of boll weevils increased only slightly when doses were increased above 3 mg.

331. ; Mitchell, E. B.; and Huddleston, P. M. 1966. Chemoreception of attractants from the cotton plant by boll weevils, Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 59: 867-868.

We obtained a significant difference in mean percentage of weevils responding following several treatments, compared with untreated weevils, but we noted a significant difference in mean ratio (attractant: control) only when 1 or both antennal clubs were removed or painted. When results from similar treatments were combined, a significantly greater response was obtained by removing or painting only 1 antennal club than by removing or painting both clubs. Our results, and the frequent behavioral action of boll weevils "cleaning" their antennal clubs with their front tarsi when they are responding to attractants strongly suggest that the organs of boll weevils that receive olfactory stimuli are situated in the club of the antenna. No differences in response attributable to sex were detected.

332. ; Mitchell, E. B.; and Huddleston, P. M. 1966. Effect of age, nutrition, sex, and time of day on response of boll weevils to an attractant from cotton. Ann. Entomol. Soc. Am. 59: 1024-1025.

We concluded that in the continuing bioassay of plant attractants for boll weevils, unsexed weevils, 4-5 daya old, fed on 10% sucrose-water solutions before testing will give the most reliable results for tests made at any time during the day. This procedure is now being used at this laboratory to bioassay attractant fractions provided by chemists.

333. ; Mitchell, E. B.; and Huddleston, P. M. 1967. Laboratory studies of sex attraction in the boll weevil. J. Econ. Entomol. 60: 1221-1224.

Laboratory studies with the sex attractant of the boll weevil, Anthonomus grandis Boheman, confirmed previous findings that the female aggressively seeks the pheromone-emitting male. In both sexes, peak activity occurred when the weevils were 4-6 days old and the other was less than 2 days old, the males were mostly unattractive and the females mostly unresponsive. Females responded to a single male, but response was significantly greater to 5, 10, or 25 males. Virgin males were twice as attractive and virgin females were 3 times as responsive as mated males or females. Males sterilized with apholate were about half as attractive to virgin females as untreated males when both were fed on laboratory diet but were equally attractive when both were fed on fresh cotton squares (flower buds). Comparisons between laboratory (medium-reared) and field (square-reared) male weevils, each fed cotton squares or laboratory diet, indicated a greater importance of food rather than strain in determining female response.

334. ; Mitchell, E. B.; and Huddleston, P. M. 1967. Procedure for bioassaying the sex attractant of the boll weevil. J. Econ. Entomol. 60: 169-171.

A newly developed laboratory bioassay procedure showed that male boll weevils, Anthonomus grandis Boheman, produce an air-borne pheromone that is attractive to females. In 1- and 16-hour tests when weevils were preconditioned by 3 different treatments, significantly more females responded to males than to females. When callow adult weevils were removed from the rearing medium before they made contact with other insects, response of females to males increases significantly over those having such contact. In 1-hour tests a slight response of males to males was observed and significantly fewer

males responded to females than to other males.

335. ; Mitchell, E. B.; Huddleston, P. M.; and Davich, T. B. 1966. A laboratory technique for bioassay of plant attractants for the boll weevil. J. Econ. Entomol. 59: 240-241.

Progress in isolating, identifying, and field testing insect attractants is dependent on reliable bioassay methods to determine the response of the insects to the attractants. The "trap flask" bioassay method of demonstrating the presence of an attractant in the cotton plant for the boll weevil, Anthonomus grandis Boheman, and of a sex attractant in the male weevil for the female proved to be unpredictable and time consuming in our later laboratory studies with these attractants. To meet the need for a more reliable procedure the following new technique was developed.

336. ; Moody, R.; Lowe, J.; and Pitts, A. 1975. Grandlure, in-field traps, and insecticides in population management of the boll weevil. J. Econ. Entomo. 68: 502-504.

When grandlure was used in conjunction with in-field traps to aggregate populations of Anthonomus grandis Boheman in 3 diverse areas of Mississippi and Alabama, ca. 6 times as many boll weevils were found in cotton near traps than in cotton 100 ft or more from traps. Also, the percentage of egg-punctured squares near traps was consistently 1.5 to 2 times higher throughout the test than in cotton 100 ft from the traps. Grandlure and in-field traps have potential in population management of boll weevils.

337. ; Wilson, N. M., Mitchell, E. B.; and Huddleston, P. M. 1971. Factors affecting activity of grandlure, the pheromone of the boll weevil, in laboratory bioassays. J. Econ. Entomol. 64: 1454-1456.

In laboratory studies with grandlure mixture, the synthetic pheromone of Anthonomus grandis Boheman, firebrick was the most effective carrier tested.

Grandlure was attractive to females at amounts as low as $5x10^{-6}$ mg but was most attractive at amounts ranging from 2.5 to 50 mg. Grandlure remained attractive longer at a given temperature when evaporation was reduced by placing a stopper or cover on the holding container. When a cotton plant extract was added to grandlure, its attractiveness was increased markedly.

338. Harding, J. A. 1970. Field tests for control of boll weevils, cabbage loopers, Heliothis and whiteflies on cotton, Weslaco. Tex. Agric. Exp. Stn. Consol. Prog. Rep. PR 2840-2845, pp. 5-7.

Sixteen chemicals applied with ground equipment at 4.3 gallons of formulation per acre were evaluated for cotton insect control in three experiments. Although adequate control was not obtained in every case, the toxicants which were statistically superior are listed for each insect with the rate per acre in parentheses: Boll weevil-toxaphene + methyl parathion (2.0 + 1.0), carbaryl + methyl parathion (2.0 + 0.5), Bayer 93820 (1.0), Union Carbide 34096 (1.5), Pennsalt TD 5032 (0.5), Ciba 9491 (2.0) and Monitor® (1.5). Cabbage looper-Ciba 9491 (2.0), Monitor® (1.5), Torak® (2.0), Galecron® (1.0), EPN® (1.0), and Azodrin® (1.0). Heliothis sp. infestations were very light, but parathion (1.5), Pennsalt TD 5032 (0.5), Galecron (1.0) and Ciba 9491 (2.0) offered promise. Whitefly control was recorded in only one test which compared two results of mixtures and one chemical with those of untreated plots. Azodrin (1.0) was outstanding for control followed by carbaryl + methyl parathion (2.0 + 0.5). Noticeable phytotoxicity was noted in plots treated with Ciba 9491 (2.0) and Pennsalt TD 5032 (0.5).

339. 1975. Boll weevil and tobacco budworm field control tests in the Lower Rio Grande Valley of Texas, 1974. Tex. Agric. Exp. Stn. Prog. Rep. PR-3362, 3 pp.

Several of the newer insecticide compounds were compared for boll weevil

and tobacco budworm control on cotton in large aerially applied plots and in small plots treated with ground machinery. Weevil damage was reduced most by Zolone (1.5 + 3.0), Carbaryl + Molasses + chlordimeform (1.50 + 0.125), Lorsban (1.0), azinphosmethyl + methyl parathion (0.25 + 1.00) and CGA 18809 (0.50) (lbs + AI/acre in parenthesis). No weevil resistance to insecticides was shown. Budworm damage was reduced most by FMC 33297 (0.05, 0.10 + 0.20). RH 218 (1.00), CGA 15324 (1.00), Methomyl (0.75) and Acephate (1.00). Several of the other compounds and mixtures resulted in reduced budworm damage to bolls equal to the above materials, but square damage was more severe.

340. , and Cowan, C. B., Jr. 1971. Infestations of seven cotton insects on pilose, glanded, frego bract and colored cotton in 1969. Tex. Agric. Exp. Stn. Prog. Rep. PR-2862, 11 pp.

Cotton aphids, Aphis gossypii Glover, and cowpea aphids, Aphis caraccivora Koch., were more numerous on pilose cotton than on smoothier varieties. Aphids were least numerous on mutant, bronze leaf, yellow green and virescent yellow cottons. The leaf miner, Liriomyza munda Frick, was more numerous on pilose cotton than on smoother cottons and least numerous on red leaf cotton. No differences in parasitism of leaf miners were detected on the various cotton types. Cotton fleahoppers, Pseudatomoscelis seriatus Reuter, were more numerous on pilose cotton than on the smoother cottons. Not enough fleahoppers were present in the colored cottons to detect differences. More fleahoppers were present on Frego Bract cottons than on their normal counterparts. The fewest fleahoppers were found on the heavily glanded XG-15; however, another heavily glanded cotton, 39, had more fleahoppers than Bayou or Deltapine Smoothleaf. The cotton leaf preforator, Bucculatrix thurberiella Busck, was most numerous on red leaf cotton and least on mutant. The boll weevil, Anthonomus grandis Boheman, did less damage to pilose, bronze leaf and red leaf cotton. Diffe-

rences between incidence of thrips, Frankliniella spp., on pilose and smoother cottons were not detectable.

341. ; Hipp, B. W.; Dupnik, T. D.; and Fuchs, T. W. 1976. Cotton density, variety and chemical element status related to insect numbers and damage. Southwest. Entomol. 1: 136-140.

During 1971 and 1972, an experiment was conducted comparing plant densities of 29,000 and 84,000/acre for each of 4 varieties. Insect numbers, damage, and element status were compared. Plant density did not affect fruiting, arthropod numbers, insect damage or concentration of elements. Several differences were found in element concentrations due to variety. Results suggested that element levels in the plant might contribute to insect levels among varieties.

342. ; Huffman, F. R.; Wolfenbarger, D. A.; and Davis, J. W. 1977. Insecticidal activity of Alpha-cyano-3-phenoxybenzyl pyrethroids against the boll weevil and tobacco budworm. Southwest. Entomol. 2: 42-45.

A substituted phenyl acetate, Shell Development SD-43775 (cyano (3-phenoxyphenyl) methyl 4-chloro-alpha-(1-methylethyl) benzeneacetate) and a pyrethroid, SD-41706 (cyano (3-phenoxyphenyl)methyl 2,2,3,3,-tetramethylcyclopropane carboxylate) were tested in the laboratory and field against the tobacco budworm, Heliothis virescens (F.), and the boll weevil, Anthonomus grandis Boheman. SD-43775 was effective against the tobacco budworm at 0.1 lb/acre in the field and SD-41706 at 0.2 lb. Resistance of the tobacco budworm to SD-43775 was shown by a 21X difference in LD_{50}'s between a laboratory-susceptible and a field collected strain. SD-43775 was found effective against the boll weevil at 0.1 lb/acre.

343. , and Wolfenbarger, D. A. 1980. Evaluation of diflubenzuron for boll weevil control in the Lower Rio Grande Valley of Texas. Southwest. Entomol. Suppl 1: 27-30.

Field experiments were conducted in 1976, 1977, and 1978 to evaluate diflubenzuron (N-[[(4-chlorophenyl)amino]carbonyl]-2, 6-difluorobenzamide, Dimilin®, TH-6040) for boll weevil, Anthonomus grandis Boheman, control. Weevil reduction was shown but not on a seasonal basis and yields were not affected. The predator complex was not adversely affected. No phytotoxicity or fruiting variations of the cotton were recorded due to treatment.

344. Harp, S. J., and Turner, V. V. 1976. Evaluation of various pheromone trap designs for effectiveness in monitoring boll weevil populations. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 10-19.

Sticky traps captured significantly greater numbers of weevils than nonsticky live traps during peak response periods. Difference between sticky and live traps when compared over the entire season, however, was not significant. Sticky traps that had a large surface area captured significantly more weevils regardless of shape. A live trap was constructed by placing a Leggett trap top on a 1-gallon milk carton wing trap. This trap was equal in trapping efficiency to the standard Leggett trap but had advantages of ease of handling and lower production costs. The standard Leggett trap was superior to the Story survey trap® in trapping efficiency because it has a larger surface area.

345. , and Turner, V. V. 1976. Field evaluation of chemicals for control of insect pests on cotton in the Texas Blacklands. Southwest. Entomol. 1: 85-90.

Insecticides were evaluated for control of cotton insect pests during the

summer of 1974 near Temple, Texas. Treatments providing the greatest degree of control of the tobacco budworm were O-ethyl O-[4-(methylthio) phenyl] S-propyl phosphorodithioate (BAY NTN 9306) at a rate of 1.5 lb AI/acre and carbaryl (Sevimol®) + chlordimeform at 1.0 and 0.125 lb AI/acre. Other treatments were comparable to the methyl parathion and monocrotophos standards. Chlorpyrifos gave quick knockdown of thrips and boll weevils but was ineffective against the tobacco budworm.

346. Harrell, E. A.; Perkins, W. D.; and Sparks, A. N. 1980. Improved equipment and techniques for mechanizing the boll weevil larval rearing system. Trans. ASAE 23: 1554-1556, 1563, 1580.

Equipment and techniques have been improved for mechanizing the boll weevil larval rearing system. The equipment is designed to form rearing trays from plastic film, fill the trays with food, rapidly cool the food, place eggs on the food, cover the eggs with a granular material, heat-seal a cover on the tray, and shear trays as desired. Trays for rearing weevils are processed at a rate that will provide slightly more than 106 weevils/h. A method of rearing weevils without using granular materilas produced 85 percent as many weevils as were produced when using the granular materials. Also, an alternate tray cover was tested, with satsfactory results, and costs one-third as much as the cover previously used.

347. ; Perkins, W. D.; Sparks, A. N.; and Moore, R. F. 1977. Mechanizing techniques for adult boll weevil, Coleoptera: Curculionidae production. Trans. ASAE 20: 450-453.

Equipment developed at the Southern Grain Insects Research Laboratory for mechanized rearing of Heliothis zea (Boddie) has been modified for rearing boll weevils, Anthonomus grandis Boheman. Plastic rearing trays are formed, filled with diet, cooled, egged, sanded, covered, and sheared in a continuous

in-line operation. Each process, except shearing, is performed at the rate of ca. 300 trays/h. The yield of weevils averages between 30 and 40 percent of eggs that hatch when placed on the diet at the rates of 200 to 300 eggs/300 cm^2. In 1 h of operation, the machine replaces $93.75 worth of plastic petri dishes for $21.25, thus reducing the cost of rearing containers by ca. 75 percent. Substantial additional savings may be expected because the need for separate functions to fill the trays with diet, egging, and sanding was eliminated.

348. Harris, F. A.; Lloyd, E. P.; and Baker, D. N. 1966. Effects of the fall environment on the boll weevil in northeast Mississippi. J. Econ. Entomol. 59: 1327-1330.

Limited studies of the preoviposition and developmental periods of the boll weevil, Anthonomus grandis Boheman, were made in the field in the fall of 1964. More extensive studies were made with simulated fall temperatures and day lengths in the laboratory during the winter 1964-65. Both field and laboratory data indicated that with the cooler temperatures of the fall, the preoviposition period of emerging boll weevils was generally longer than that of weevils emerging earlier in the season, though some individual females had a preoviposition period shorter than 1 week until night temperatures dropped to 50°F or lower. Each developmental stage of the boll weevil was considerably longer, with cooler temperatures and shorter photoperiods. The total developmental period from egg to adult was as short as 24 days when eggs were laid in squares early in September and as long as 60 days when eggs were laid in bolls in mid-September. The time to emergence of adult boll weevils from eggs deposited on a given date in the fall showed a wide range. The data indicated that an egg laid on or after October 1 would not contribute to the overwintered population of weevils.

349. ; Lloyd, E. P.; Lane, H. C.; and Burt, E. C. 1967. Influence of light on diapause in the boll weevil. I. Dependence of diapause response on the spectral composition of the light used to extend the photoperiod. J. Econ. Entomol. 60: 1565-1567.

Regions of the near-ultraviolet and visible spectrum effective for inducing diapause suppression in the boll weevil, Anthonomus grandis Boheman, were investigated. One group of weevils was exposed to 11 hours of fluorescent light-time and 13 hours of dark-time that initiated diapause (L11:D13); the 2nd group was exposed to 13 hours of fluorescent light-time and 11 hours of dark-time that inhibited diapause (L13:D11). A 3rd group was exposed to 11 hours of fluorescent light-time followed by 2 hours of illumination with narrow wavebands of light of different spectral compositions and 11 hours of dark-time (L11+2:D11). The spectral region most effective for suppressing diapause was found to be between 400-655 nm. The 359-390 nm and 670-1000 nm spectral regions were less effective.

350. ; Shaunak, K. K.; Wilson, C. A.; Hurst, G. A.; and Simmons, C. L. 1976. Effects of the Pilot Boll Weevil Eradication Experiment on non-target species. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.], ARS-S-71, pp. 113-118.

A study of the impact of an eradication program on nontarget species is an important and necessary part of any pilot experiment which may lead to large programs. The Environmental Protection Agency requires an environmental impact statement before it will approve programs such as an attempt to eradicate the boll weevil throughout the Cotton Belt. Furthermore, the side effects from an eradication program must be figured into the assessment of costs and expected benefits of the program. Thus, the side effects of the Pilot Boll Weevil Eradication Experiment (PBWEE) on certain nontarget organisms were

monitored. The monitoring activities were concentrated in the following three areas: (1) Impact on cottonfield-inhabiting nontarget insect species, including both insect pest species and natural enemies; (2) impact on honey bees frequenting cottonfields from beehives in the vicinity; and (3) impact on nontarget wildlife species.

351. Harwalkar, M. R.; Haynes, J. W.; and Mitlin, N. 1974. A quick staining procedure to determine the testicular damage to boll weevils sterilized with busulfan. Entomol. Exp. Appl. 17: 319-321.

The region surrounding the germarium of a normal untreated testes is intensely stained and appears as a discrete band in the middle region. This region is constituted of spermatocytes in various stages of development. In the treated testes, this region has disintegrated, since the identity of the discrete band is lost, probably because of the disappearance of the spermatocytes. All areas of treated testes took less stain than untreated testes, an of the spermatocytes. All areas of treated testes took less stain than untreated testes, an indication that fewer germ cells were present. However, the germarial area of treated testes was more densely stained than other areas. Evidently the sperm below the germarium take up the stain and the germarium appears more intact. We surmise that the granular structures in the germarium region in the treated testes are the disintegration products of germarial and spermatocyte cells. However, their exact nature could not be determined. The differences in staining pattern between untreated and treated testes were clear, and we had no difficulty in assessing them. However, we could not precisely correlate the degree of sterility of substerilized weevils (those fed for 1-5 days) with the results of the staining procedure. Thus the testes from males fed busulfan 1 or 2 days were comparatively little damaged and the staining pattern was almost normal. Weevils fed 3 days had more damage (alveit variable) and intermediate or incomplete sterility, and the staining pattern resembled neither completely

normal nor sterilized testes. Weevils fed longer periods were progressively more sterile, showed progressively more damage, and took on the pattern of staining of sterilized testes.

352. Hayes, D. K.; Schechter, M. S.; Mensing, E.; and Horton, J. 1968. Oxygen uptake of single insects determined with a polarographic oxygen electrode. Anal. Biochem. 26: 51-60.

When the oxygen uptake of live insects was determined by using a polarographic electrode and a buckout circuit was placed in series with commercially available equipment, small changes in oxygen tension could be detected at a sensitivity 100-fold greater than that provided by the unmodified instruments. The test was made by placing the insect in a closed chamber so designed that the oxygen utilization of insects weighing between 60 and 500 mg could be measured. The rates of respiration of four species of insects determined by this method were in good agreement with those obtained by other investigators with manometric techniques.

353. Haynes, J. W. 1978. The effect of diflubenzuron plus busulfan or apholate on the mass-reared ebony strain of boll weevils. J. Ga. Entomol. Soc. 13: 256-260.

When female Anthonomus grandis Boheman from a mass-reared ebony strain were dipped four times on 0.4% diflubenzuron and mated with untreated males the F_1 adult emergence was only 3%. Weevils fed 0.1% busulfan treated diet for 4 days or in combination with 0.4% diflubenzuron plus two dips of 2.5% apholate reduced adult emergence to 5% in treated males with untreated females.

354. ; Davich, T. B.; Mitlin, N.; and Sloan, C. E. 1971. Shipment of large numbers of boll weevils in small containers. J. Econ. Entomol. 64: 325-327.

No appreciable mortality was observed in 4-8 hr anesthetized weevils; the mor-

tality was 2-4 times greater than the control after 15-24 hr of anesthetization; 30-48 hrs without oxygen killed 3-5 times the number held in the control. Boll weevils anesthized with nitrogen and held at 10°C for 24 hr did not die at any higher rate than the control for the first week posttreatment.

355. ; Dawson, J. R.; and Borkovec, A. B. 1976. Effects of chemosterilant fumigation on the mortality and sterility of boll weevils. U.S. Agric. Res. Serv. [Rep.], ARS-S-132, 6 pp.

Laboratory experiments, using a simple closed-flask method and some highly active chemosterilants, were conducted to determine the effectiveness of fumigation as a method of sterilizing the boll weevil, Anthonomus grandis Boheman. After fumigation, males and females were separated, mated with normal, untreated boll weevils, and fed fresh diet pellets. A maximum 50 eggs were collected each week for 3 weeks after treatment. Half the eggs were checked daily for hatch, and half were implanted and observed 21 days for adult emergence. Funigation was generally an effective sterilizing technique. The alkylating fumigants tepa, thiotepa, metepa, and P,P-bis (1-aziridinyl)-N-methylphosphionothioic amide (ENT-61585) were effective in sterilizing 92 to 100 percent of treated males for 3 weeks, and fecundity of treated females was reduced to 88 to 100 percent. Tepa, thiotepa, and ENT-61585 were the most active compounds tested at 30° C and required only half the time of metepa or P,P-bis (1-aziridinyl)-N-methylphosphinic amide (ENT-51254) to sterilize boll weevils. The non-alkylating fumigants hempa and hexamethylphosphorothioic triamide (ENT-50918) were effective in reducing egg hatch, but recovery of fertility occurred 3 weeks after hempa treatment. None of the mixtures of the fumigant compounds was more effective as a sterilant than the individual compounds.

356. ; Dawson, J. R.; Mitlin, N.; and Davich, T. B. 1976. Quality control assessments of male sterility during the 1972 and 1973 Pilot Boll Weevil Eradication Experiment. Miss. Agric. For. Exp. Stn. Tech. Bull. 81, 7 pp.

Male boll weevils were sterilized with 0.09% busulfan in 1972 and 0.09% busulfan + 0.4% hempa in 1973. Sterility during 1972 averaged 95, 72, and 86% after 1, 2, and 3 weeks posttreatment. In 1973 sterility averaged 97, 87, and 88% after 1, 2, and 3 weeks, respectively.

357. ; Dawson, J. R.; Mitlin, N. and Paulk, J. I. 1978. Sterilization of the boll weevil by radioactive fumigation. J. Ga. Entomol. Soc. 13: 345-350.

[85]Krypton applied as a fumigant to the boll weevil, Anthonomus grandis Boheman, was capable of sterilizing the insect. Activities of 2 and 7 Curies were used with the latter giving more uniform results. Both sexes could be sterilized.

358. ; Harwalkar, M. R.; and Mitlin. N. 1973. Quantitative studies of busulfan-treated diet necessary to sterilize the male boll weevil. J. Econ. Entomol. 66: 1338-1339.

Individual weevils fed 0.1% busulfan diet for 6 days consumed 30.3±2.5 mg of diet compared to 31.0±3.6 mg of food consumed by the control. Similar results were obtained in 6-day mass-feeding test (50 weevils): 22.8±1.3 mg of 0.1% busulfan-treated diet was consumed/weevil, vs. 23.2±1.5 mg of untreated diet consumed/weevil in the control. These data agree with earlier studies where 33 mg of a control diet was consumed/weevil after 5 days. After 2-3 days, 8.5-8.8 mg of treated diet was eaten resulting in 33% egg hatch, vs. 65-73% egg hatch in the control. A 4-5 day feeding of treated diet resulted in further reducing the egg hatch by 25-28% over the 2 previous days. It was found that 15.3 mg of treated food (50% of the total 6-day consumption) was

eaten in 4 days, resulting in 7.5% egg hatch. Control weevils ate 15.7 mg of untreated diet (51% of total consumption) after 4 days, and the egg hatch was 57.8%. The 6-day feeding of 0.1% busulfan-treated diet (30.3 mg consumed/weevil) reduced egg hatch to 2%, vs. 72.6% egg hatch in the control.

359. ; Hedin, P. A.; and Davich, T. B. 1966. Hempa and apholate as chemosterilants for the boll weevil. J. Econ. Entomol. 59: 1014-1015.

Concentrations of 5-50% hempa resulted in 24-76% fewer adults and 5-15% apholate dips produced 77-79% fewer adults than the control. Hempa was much less toxic than apholate.

360. ; Mattix, E.; Mitlin, N.; Borkovec, A. B.; and Lindig, O. H. 1976. New chemosterilants for boll weevils. U.S. Agric. Res. Serv. [Rep.], ARS-S-131, 30 pp.

Thirty-two of 295 compounds tested were effective chemosterilants on mixed sex boll weevil groups when the compounds were fed for 3 days in an adult diet. Fourteen of the 32 chemosterilants were aziridinyl compounds. When the treated weevils were outcrossed to normal male and female weevils, the following compounds were the most effective: N,N'-1, 5-naphthylenebis-(1-aziridinecarboxamide) (ENT-50664); 1,1'-methylenebis (aziridine) (ENT-50752); P-(1-aziridinyl)-N,N,N,N'-tetramethylphosphonic diamide ENT-50991); butyl bis (1-aziridinyl) phosphinate (ENT-61354); P, P-bis (1-aziridinyl)-N-propylphosphionothioic amide (ENT-61580); P, P-bis (1-aziridinyl)-N-ethylphosphinothioic amide (ENT-61581); bis(1-aziridinyl) ethylphosphine sulfide (ENT-61587); 1,9-nonanediol dimethanesulfonate (ENT-26397); N-fluorne-2-ylacetohydroxamic acid (ENT-50466); 1-nitro-3-[(2-pyridylmethylene) amino] guanidine (ENT-52077); and m-(salicylideneamino) phenol (ENT-52102).

361. , and Mitchell, E. B. 1977. Fractionated irradiation of boll weevils during pupal development: Effect of sperm depletion and transfer as measured by female responsiveness. J. Econ. Entomol. 70: 411-412.

After virgin matings with sterile males (previously mated -03 times) the responsiveness of females of Anthonomus grandis Boheman to grandlure was twice that of females mated with normal males. The higher responsiveness of females mated with sterile males indicate 0-66% fewer sperm were transferred to the spermathecae and these females continued seeking other males. After 3 matings, sperm transferred by ^{60}CO irradiated males was reduced by 67% or more.

362. ; Mitlin, N.; Davich, T. B.; Dawson, J. R.; McGovern, W. L.; and McKibben, G. H. 1977. Sterilization of boll weevil pupae with fractionated doses of gamma irradiation. Entomol. Exp. Appl. 21: 51-62.

Fractionated doses of 6,250-8,000 rads of gamma irradiation when administered to pupae of the boll weevil, A. honomus grandis Boh., sexually sterilized both sexes. Mortality of males thus treated with 6,250 and 8,000 rads via fractionation was 14% and 27% respectively, by 5 days posttreatment compared with 46% mortality when an equivalent acute dose was administered to newly emerged adults. Pheromone production of males irradiated at 6,250 rads was one-third that of the control for the first 4 days, but equal that of the control during 5-11 days posttreatment. This procedure lends itself to the large-scale sterilization of weevils needed in an eradication program. This technique is applicable to other insects that are highly susceptible to acute doses.

363. ; Mitlin, N.; Davich, T. B.; Dawson, J. R.; Woods, C. W.; and Terry, P. H. 1972. Chemosterilants screened against the boll weevil in dipping and feeding tests. U.S. Dep. Agric. Prod. Res. Rep. 141, 21 pp.

Ninety-eight candidate chemosterilants were tested in dipping and feeding tests on the boll weevil. 2-Pyridinethiol 1-oxide sodium salt and tretamine

in dipping tests at 1 and 1.5% reduced egg laying in treated females to 0 and mortality was 0 and 22%, respectively, after 14 days. Hempa when fed to males at 0.15 and 0.2% reduced adult emergence to 0 and mortality was 25 and 5%, respectively, after 14 days.

364. ; Mitlin, N.; Davich, T. B.; Nail, B. J.; and Dawson, J. R. 1975. Mating and sterility of male boll weevils treated with busulfan plus hempa. Environ. Entomol. 4: 315-318.

Male Anthonomus grandis Boheman fed 0.08% busulfan + 0.4% hempa for 6 days were as competitive as untreated males about 1/2 the time (occurring randomly), and 1/2 the time the treated males were 1/4-1/3 as competitive as untreated males. After an average of 7 matings, the treated males had depleted their supply of sperm. Determinations of sterility based on testes examination were in full agreement 91% of the time with determinations based on egg hatch and adult emergence.

365. ; Mitlin, N.; Davich, T. B.; and Sloan, C. E. 1971. Evaluation of candidate chemosterilants for the boll weevil. U.S. Dep. Agric. Prod. Res. Rep. 120, 24 pp.

Two hundred candidate chemosterilants were tested on the boll weevil and 27 sterilized > 75% of the eggs collected. In all but 6 cases the mortality was > 30%. A 12% concentration of 1-aziridinecarboxamide, N, N'-1, 50napthylenebis-, a 1.5% concentration of tretamine, and 10% concentration of urea 1-[bis(1-aziridinyl) phorphinyl]-3-(3, 4-dichlorophenyl) tested on mixed sexes by dipping sterilized 91, 93, and 100% of the eggs, respectively, and mortality was 12, 11, and 40%, respectively, after 14 days. In combination tests 1% apholate + 1% piperonyl butoxide, 1% Bucarpolate, or 2% carbazole sterilized 100, 86, and 94% of the eggs and mortality was 30, 15, and 10%, respectively.

366. ; Mitlin, N.; Sloan, C. E.; and Dawson, J. R. 1973. Busulfan: development of improved methods of sterilizing boll weevils. J. Econ. Entomol. 66: 619-622.

The standard method of sterilizing Anthonomus grandis Boheman (6-day feeding of 0.1% busulfan, 1-4-butanediol dimethanesulfonate) adequately sterilizes males but does not induce a high degree of sterility in females, and mortality is less than 40% after 2 weeks. Feeding higher concentrations of busulfan alone or lower concentrations of busu fan in combinations with methotrexate, hempa, or apholate for 6 days or less or feeding 0.1-0.2% busulfan followed by low doses of gamma radiation induces virtually complete sterility in both sexes but causes fairly high mortality. A 4-day feeding of 0.2% busulfan + 0.25% methotrexate resulted in complete sterility in females and almost complete sterility in males, and mortality was less than 40% by 3 weeks after treatment.

367. , and Wright, J. E. 1979. Fumigation of boll weevil pupae with bisazir to induce sterility. J. Econ. Entomol. 72: 823-825.

When pupae of Anthonomus grandis grandis Boheman were fumigated for 5 h in a circulating, saturated atmosphere of bisazir, 99% of the males were sterilized, and egg laying by treated females outcrossed with normal weevils was reduced by 90.6%. Sterile males transferred 11.8% more sperm than control males the 1st week posttreatment but 42.6% less the 2nd week.

368. ; Wright, J. E.; Davich, T. B.; Roberson, J.; Griffin, J. G.; and Darden, E. 1978. Boll weevil: experimental sterilization of large numbers by fractionated irradiation. J. Econ. Entomol. 71: 943-946.

Boll weevils, Anthonomus grandis grandis Boheman, 9 days after egg implantation in the larval diet were transported from the Boll Weevil Research Laboratory, Mississippi State, MS, to the Comparative Animal Research Laboratory, Oak Ridge, TN, and irradiated with 6.9 krad (test 1) or 7.2 krad (test 2) of ^{60}Co gamma

rays delivered in 25 equal doses over 100 h. In test 1, from 600 individual pairs of T (treated) ♂ X N (normal) ♀, only 114 eggs hatched from a sample of 950 eggs, and 47 adults emerged from a sample of 1042 eggs. Also, from 600 pairs of T ♀ X N ♂, 6 eggs hatched of a sample of 6 eggs and 12 adults emerged from a sample of 20 eggs. In test 2, from 700 individual pairs of T ♂ X N ♀, 54 eggs hatched from a sample of 1510, and 10 adults emerged from a sample of 1703 eggs. Also, in T ♀ X N ♂ matings, 1 egg hatched of a sample of 3, and no adults emerged from a sample of 4. Transportation and handling in the 2nd test reduced adult emergence in avg of 49%. Thus the 2 replicates in test 2 resulted in 3.4×10^5 and 4.3×10^5 irradiated weevils emerging/day for 7 days. Bacterial contamination of weevils was low.

369. ; Wright, J. E.; DeMilo, A. B.; and Borkovec, A. B. 1979. Antifertility effects of compounds screened against the boll weevil, Anthonomus grandis Boheman. Miss. Agric. For. Exp. Stn. Tech. Bull. 96, 7 pp.

Penfluron was the most effective of 17 sterilants tested by feeding or dipping boll weevils. A 3 day feeding of 0.1-0.4% or a 0.25-2% single dip totally sterilized both sexes for 2 weeks posttreatment.

370. ; Wright, J. E.; and Mattix, E. 1979. Fractionated vs. acute irradiation: the effects of treating adult boll weevils (Coleoptera: Curculionidae) at different ages. Entomol. Exp. Appl. 26: 61-66.

When 6-7-days old mass-reared ebony boll weevils, Anthonomus grandis Boheman, were given 25 doses of γ-irradiation totaling 6625 rads, mortality was 14%-15% less 1 week later than when young weevils (1-2 day-old) were similarly treated. However, giving older weevils an acute dose of 6625 rads did not reduce mortality. Seven-day-old weevils receiving the acute treatment mated 10% more than weevils that were 3 days old at the time of treatment. Seven-day-old male weevils exposed to the fractionated treatment transferred sperm

to 12% more females than 7-day-old males exposed to the acute treatment.

371. Hedin, P. A. 1969. Chemical components in the cotton plant and their effect on boll weevil behavior. In Insect-Plant Interactions; Report of a Work Conference, pp. 29-30. National Academy of Sciences, Washington.

A summary of work from 1962-1969 was presented on chemical components isolated from the cotton plant, Gossypium hirsutum L., and their effect on boll weevil (Anthonomus grandis Boh.) behavior. Feeding stimulations and attractancy were found to be elicited by a profile of plant compound, not individuals. The identity of the components was reported.

372. . 1976. Grandlure development. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 31-33.

In the initial chemical work, extractions of males with dichloromethane produced a substance that was consistently attractive to females, but a similar extract of mixed insects was unattractive to females. When the male extract was steam-distilled, the solvent extract of the distillate proved to have greater attractiveness for females than any of the other extracts that had previously been prepared. Assays of the steam distillate in concentrations as low as one male equivalent, and simultaneous assays of live males, indicated that approximate quantitative removal of the attractant had been obtained. When the frass of males, and later, mixed sexes was steam-distilled, it also was highly attractive to males (Tumlinson et al. 1968). Because the frass could be collected from the mass-rearing facility, which was primarily being used for the production of sterile males, over 50 kg was eventually obtained and processed for isolational work at only a nominal direct cost. However, it is estimated that 6 million additional insects were used for this work. Our next step was to fractionate the distilled extract on a silica gel

chromatographic column. The activity could not be found in any single fraction, but returned on recombination of two of the fractions. Thus, we were faced with elucidation of a multicomponent mixture. Considerable removal of nonactive components was achieved by chromatographing the two active fractions on silica gel silver nitrate columns and then bioassaying appropriate fractions in combination until activity was demonstrated again. Gas chromatography was then used to separate the two alcohol components which could not be separated by column chromatography. Now we knew of three separate components which had to be present for activity. Later, on an open tubular column, we were able to separate the cis and trans forms of the aldehyde, at which time we realized that four components were required.

373. . 1976. Seasonal variations in the emission of volatiles by cotton plants growing in the field. Environ. Entomol. 5: 1234-1238.

The volatiles emitted by growing cotton, Gossypium sp. in the open field were collected daily during June to September 1957 by pulling an air stream through a porous polymer and then desorption with pentane. From analysis by GLC and GLC-MS, a total of 70 compounds was identified, only 15 of which were also found in cotton bud essential oil. The amount of total volatiles collected reached a maximum in late July and early August when the cotton plant squaring and flowering was highest. Then production decreased, to some degree with continued fruit set and more rapidly with approaching senescence. Although the sex pheromone of the boll weevil is a more powerful attractant than the plant for this insect, the plant may play some role in its migration.

374. . 1976. Using a sex attractant for insect control. Am. Chem. Soc., CHEMTECH 6 (July): 444-459.

The problem is the interaction of the boll weevil with the cotton plant - a

problem that costs US farmers over $300 million annually. The solution discussed is exemplary of new, environmentally safe methods of insect control - attraction to traps using synthetic, reproduction - associated odorants, called pheromone.

375. . 1977. A study of factors that control biosynthesis of the compounds which comprise the boll weevil pheromone. J. Chem. Ecol. 3: 279-289.

Biosynthesis of the four monoterpene compounds that comprise the pheromone of the male boll weevil, Anthonomus grandis Boheman, [1, (+)-cis-2-isopropenyl-1-methylcyclobutaneethanol; II, (Z)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol; III, (Z)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde; and IV, (E)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde] was studied. More pheromone was biosynthesized in the summer months, somewhat less was produced by males in the presence of females than by isolated males, and the pheromone was concentrated in the gut and surrounding tissue of the abdomen of the males. Incubation of abdomens with the pheromone alcohols yielded related hydrocarbons, aldehydes, and alcohols, which suggested the presence of several enzyme systems. Boll weevils were able to allylically oxidize myrcene and limonene to alcohols, a capability that suggests pheromone precursors may be at least in part inhaled rather than ingested. The hemolymph may then transport the precursor to the gut or some alternative site where allylic oxication to the pheromone occurs.

376. ; Gueldner, R. C.; Henson, R. D.; and Thompson, A. C. 1974. Volatile constituents of male and female boll weevils and their frass. J. Insect Physiol. 20: 2135-2142.

The volatile constituents of male and female boll weevils, Anthonomus grandis, and their frass were analysed by GLC-MS. The 4 previously identified components of the male pheromone were present only in the male volatile oil (3·9%).

The compounds found in one or both sexes and their frass include 26 carbonyls, 23 hydrocarbons, 12 alcohols, 6 phenols, 4 esters, 3 furans, 1 ether, and 1 lactone. Also found were 2 compounds containing nitrogen, 1 halogen, and 1 sulphur. There were 33 terpenes and 24 aromatic compounds. 3,7-Dimethyl-1-octanol comprised 15·6 percent of the male frass oil. Carvone was found only in females (5·4%) and in female frass (6·8%). A series of monoterpene aldehydes (M + 152) were found only in the female frass oil. A pheromone role for these components was suggested.

377. ; Gueldner, R. C.; and Thompson, A. C. 1976. Utilization of the boll weevil pheromone for insect control. In Morton Beroza (ed.), Pest Management With Insect Sex Attractants and Other Behavior-Controlling Chemicals, pp. 30-52. American Chemical Society, Washington.

In 1969, four terpenoid compounds were demonstrated by identification and synthesis to comprise the boll weevil pheromone. Since then the pheromone has been utilized successfully for monitoring and population reduction and has been a component in several integrated pest management and elimination programs. In the course of these tests, it was necessary to develop a long-lasting formulation, to determine the best ratio of components, to improve the methods of syntheses to reduce costs, to commence registration with EPA, and to develop efficient traps and trapping procedures. The pheromone was effectively utilized in the recent South Mississippi tests to monitor and reduce the insect population. Plans for future tests are discussed. Recent studies showed that gut microflora, deficient diets, and sterilization decrease pheromone biosynthesis.

378. ; Hardee, D. D.; Thompson, A. C.; and Gueldner, R. C. 1974. An assessment of the life time biosynthesis potential of the male boll weevil. J. Insect Physiol. 20: 1707-1712.

The four monoterpene compounds [1, (+)-cis-2-isopropenyl-1-methycyclobutaneethanol; II, (Z)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol; III, (Z)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde; and IV, (E)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde] which comprise the pheromone of the male boll weevil, Anthonomus grandis, were determined daily throughout the life span of the insect by GLC analysis of the whole body and the frass. The total content of the components in the male is never greater than 210 ng, the average content in the frass produced during 1 day is 1268 ng, and the lifetime production is at least 40,000 ng. The ratio of the four components in frass is 6:6:2:1/I;II:III:IV. None of the four components was found in females, but female frass contained traces in three instances. These data can be used to compare the potential attractancy of insects from various geographical areas, at different seasons, in different nutritional states, and after chemosterilization. Such differences in potential insect attractiveness could be crucial to effective large-scale control programes.

379. ; Jenkins, J. N.; and Maxwell, F. G. 1977. Behavioral and developmental factors affecting host plant resistance to insects. In P. A. Hedin (ed.), Host Plant Resistance to Pests. Symposium Series, American Chemical Society, Ch. 16: pp. 231-275.

Aspects reviewed included biologically active compounds in plants affecting insect behavior including feeding stimulants, plant attractants, feeding deterrents, repellents, oviposition stimulants. The effects of toxins on growth in the European corn borer, Heliothis spp. and legume insects, and nutritional factors in plants affecting survival and development of insects including antibiosis and preference were also reviewed.

380. ; Lindig, O. H.; Gueldner, R. C.; and Thompson, A. C. 1975. A study of the air space volatiles present in a boll weevil mass rearing facility. J. Econ. Entomol. 68: 592-594.

The air-space volatiles present in the Robert T. Gast Rearing Laboratory at Mississippi State, Miss., were determined by pulling an air stream through a pourous polymer, desorbing the volatiles with pentane, and analyzing them by GLC-MS. The volatiles from the diet, the diet wax, and the insects (Anthonomus grandis Boheman) were similarly analyzed in an attempt to identify the sources of the volatiles in the air space. A total of 168 compounds was identified from these sources including 35 aliphatic hydrocarbons, 30 aliphatic alcohols, 26 aliphatic carbonyl compounds, 23 aromatic hydrocarbons, 13 aromatic carbonyl compounds, 7 phenols and cresols, 7 gamma-lactones, 6 ethers and furans, 5 aromatic alcohols, 5 heterocyclin compounds, 8 phthalates, and 3 other esters. The low molecular weight alcohols, carbonyl compounds, esters, and a pyrazine present chiefly in the diet volatiles were attributed to microbial contamination. The gama-lactones were believed derived during the cooking of the diet, and most of the n-alkyl hydrocarbons were derived from the diet wax. The facility mechanical plant was presumably the source of a number of aromatic hydrocarbons that are typical trace constituents of industrial oils. Small amounts of the pheromone alcohols present in boll weevils were found in the rearing facility air-space, but none were found in the insects themselves.

381. ; Lindig, O. H.; Sikorowski, P. P.; and Wyatt, M. 1978. Suppressants of gut bacteria in the boll weevil from the cotton plant. J. Econ. Entomol. 71: 394-396.

Several constituents of the cotton plant, Gossypium hirsutum L., including gossypol, caryophyllene, gallic acid, and tannins, were identified as effective suppressants of gut bacteria found in Anthonomus grandis Boheman.

A diet containing the high gossypol fraction from cottonseed as the principal protein source suppressed the growth of gut bacteria and slightly improved egg hatch of this insect.

382. ; McKibben, G. H.; Mitchell, E. B.; and Johnson, W. L. 1979. Identification and field evaluation of the compounds comprising the sex pheromone of the female boll weevil. J. Chem. Ecol. 5: 617-627.

The terpenoid compounds (+)-cis-2-isoperpenyl-1-methylcyclobutaneethanol (I), (Z)-3,3-dimethyl-$\Delta^{1,8}$-cyclohexaneethanol (II), and β-caryophyllene were isolated from frass of the female boll weevil (Anthonomus grandis Boheman). In laboratory bioassays, a mixture of these components attracted primarily males, whereas the male pheromone, grandlure, attracted primarily females. The addition to the cotton bud hydrocarbons, α-pinene, mircene, and l-limenene, improved the response by males so that the potency of the mixture was comparable to that of grandlure for females. In field test, I+II+hydrocarbons attracted both sexes, but grandlure alone and grandlure + hydrocarbons were more effective.

383. ; Miles, L. R.; Thompson, A. C.; and Gueldner, R. C. 1972. Constituents of the boll weevil. V. Factors inhibiting larval development. J. Econ. Entomol. 65: 1232-1235.

Solvent extracts from larvae and adults of Anthonomus grandis Boheman produced numerous morphological changes when they were applied topically (1-100 μg/insect) to larvae and pupae; egg hatch also was decreased. The extracts possessed a potency (ED_{50} = 1-25 μg/insect) comparable to that of synthetic cecropia juvenile hormone (a mixture of isomers). Larval development was arrested for 3-4 weeks when larvae were treated with the acetone and petroleum ether extracts.

384. ; Miles, L. R.; Thompson, A. C.; and Gueldner, R. C. 1972. Constituents of the boll weevil. VI. Effect of free fatty acid content on larval development. J. Econ. Entomol. 65: 1284-1286.

When isolated free fatty acids (FFA) and methyl ester fatty acids (MEFA) from larvae of Anthonomus grandis Boheman were applied topically to larvae and pupae, juvenile hormonelike characters such as retardation, arrest, formation of intermediates, and deformities occurred. Effective doses of both standard and isolated unsaturated FFA and MEFA were (ED_{50}) 25-30μg for larvae and 15-20 μg for pupae. The FFA in larvae does not exceed 9 μg. The endogenous FFA levels drop significantly during larval development, reaching a minimum just before the onset of pupation.

385. ; Miles, L. R.; Thompson, A. C.; and Minyard, J. P. 1968. Constituents of a cotton bud. Formulation of a boll weevil feeding stimulant mixture. J. Agric. Food Chem. 16: 505-513.

Highly active feeding (puncturing) stimulant mixtures were formulated for the boll weevil (Anthonomus grandis Boheman) from known cotton constituents, common metabolites, and compounds inducing primary mammalian sensations of taste and odor. Of 286 compounds bioassayed individually, 52 elicited substantial activity, and 14 of these had previously been reported in cotton. The insect was found to express preference for sweet, sour, and cooling taste properties, but odor preferences were difficult to establish. Compatability of the individually active components were necessary for formulation of active mixtures. An 8-component mixture of β-sitosterol, 15 pentadecanolide (15-hydroxypentadecanoic acid ξ-lactone), 1,8-cineole (1,8-epoxy-p-methane), N,N-dimethylaniline, vanillin, mannitol, rhamnose, and 0.1 M phosphate buffer, pH 7.0, was superior to cottonseed oil and competitive with aqueous bud extract baits.

386. ; Rollins, C. S.; Thompson, A. C.; and Gueldner, R. C. 1975. Pheromone production of male boll weevil treated with chemosterilants. J. Econ. Entomol. 68: 587-591.

The production of the 4 monoterpene compounds that comprise the pheromone of Anthonomus grandis Boheman (I, (+) -cis-2-isopropenyl-1-methylcyclobutaneethanol; II, (Z)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol; III, (Z)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde; and IV, (E)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde) was determined from amounts in the feces of male weevils fed diets with and without chemosterilants. Cotton buds, the natural food source of the insect, promoted a higher level of pheromone biosynthesis bye the insects than did the laboratory diet, mostly because weevils fed the laboratory diet produced lesser amounts of the aldehydes (III and IV). Insects fed apholate or busulfan produced markedly less of the alcohols (I and II) compared with insects fed cotton buds or diet without chemosterilants. Furthermore, the chemosterilants caused a proportional decrease in the formation of II relative to I and III.

387. ; Thompson, A. C.; and Gueldner, R. C. 1973. The boll weevil-cotton plant complex. Toxicol. Environ. Chem. Rev. 1: 291-351.

The boll weevil, Anthonomus grandis Boheman was introduced from Mexico into the United States about 1892. More than three-fourths of all insect losses to cotton in this country have been attributed to this insect, and it is generally agreed that cotton cannot be profitably grown in areas where it occurs without adequate control measures. This review summarizes the chemically oriented research conducted on this plant-insect complex during the past seventy years with emphasis on the program conducted since 1962 at the Boll Weevil Research Laboratory. Plant-insect relationships, host plant resistance, feeding stimulants, plant attractants, and plant constituents are discussed. Insect-insect relationships treated include insecticides,

chemosterilants and hormones, sex attractants, and insect constituents. The development of an integrated program for the attempted eradication of this insect is also discussed.

388. ; Thompson, A. C.; and Gueldner, R. C. 1975. Cotton plant and insect constituents that control boll weevil behavior and development. In Biochemical Interaction Between Plants and Insects. Recent Adv. Phytochem. 10: 271-350.

The aspects of plant-insect interactions, discussed in previous sections of this review, have dealt primarily with laboratory or field experiments of that aspect. The thrust of the boll weevil research program of the past 15 years was to develop a multidisciplinary technology to eliminate the insect. From 1970 to 1974 a considerable number of field tests were done, including the South Mississippi Pilot Boll Weevil Eradication Experiment (1971-1973). Elements of plant-interaction have been included in most of the test regimens, so it is on this basis that the results will be discussed.

389. ; Thompson, A. C.; and Gueldner, R. C. 1975. Survey of the air space volatiles of the cotton plant. Phytochemistry 14: 2088-2090.

When the air space volatiles of cotton grown in the greenhouse were collected and concentrated, they were found to possess a cotton plant odor. Upon analysis 54 compounds were identified: 4 aliphatic hydrocarbons, 17 aromatic hydrocarbons, 4 aliphatic and alicyclic carbonyl compounds, 4 aromatic carbonyl compounds, 9 aliphatic and alicyclic alcohols, 2 aromatic alcohols, 5 ethers and furans, 4 phthalates, and 4 miscellaneous compounds. Only 6 compounds, nonanal, benzaldehyde, cumic aldehyde, 1-hexanol, isoborneol, and benzyl alcohol were also found in cotton bud essential oil. In contrast, the cotton bud essential oil has been found to contain at least 30 monoterpene and sesquiterpene hydrocarbons and alcohols, 2 sesquiterpene oxides, 14 carbonyl compounds and 12 other

alcohols and phenods. In earlier work on the components in the cotton bud essential oil that contributed to attraction, a mixture of β-bisabolol, β-carophyllene oxide, β-caryophyllene, α-pinene, and limonene effectively attracted boll weevils in laboratory bioassays. Later, several mixtures of commercially available terpenoids proved to be nearly as attractive as extracts of cotton buds. In view of the diversity of the compounds found in the air space volatiles, it was concluded that no individual chemical is likely to be attractive in itself.

390. ; Thompson, A. C.; Gueldner, R. C.; and Henson, R. D. 1974. Analysis of the antimicrobial agents, potassium sorbate and methyl-p-hydroxybenzoate, in boll weevil diets. J. Econ. Entomol. 67: 147-149.

Analytical procedures were developed to determine whether the antimicrobial agents methyl-p-hydroxybenzoate and potassium sorbate had been constituted properly in 2 diets for larvae of Anthonomus grandis Boheman and whether they were stable to the heat provided by autoclaving or flash sterilizing, to pH 5.5, to other dietary constituents, and to continued dispersal in the diet at room temperature for 2 weeks. Both TLC-UV and GLC procedures gave average recoveries above 95%. Thus, no degradation problems were evident. These agents are used to preserve foodstuffs from molds, yeasts, and bacteria.

391. ; Thompson, A. C.; Gueldner, R. C.; and Minyard, J. P. 1972. Volatile constituents of the boll weevil. J. Insect Physiol. 18: 79-86.

When the distillable oil from adult boll weevils, Anthonomus grandis, of both sexes was investigated with an integrated gas chromatography-mass spectrometry system, evidence was obtained for a number of mono- and sesquiterpene hydrocarbons and some substituted anilines including o-toluidine; for some C_5 and C_6 alcohols and monoterpene alcohols; and for at least one sesquiterpene alcohol. The major componnts were a series of alkanes, alkenes,

and alkyl alcohols of high molecular weight. This investigation was part of a study made to identify possible additional components of the pheromone produced by the boll weevil.

392. ; Thompson, A. C.; and Minyard, J. P. 1966. Constituents of the cotton bud. III. Factors that stimulate feeding by the boll weevil. J. Econ. Entomol. 59: 181-185.

Components of the cotton bud that stimulate feeding by the boll weevil, Anthonomus grandis Boheman, were fractionated. Studies with different solvents and column chromatography provided evidence that 3 cotton-bud components having diverse chemical characteristics were present and elicited response from the weevil. Response of the insect was modified by factors such as pH, light, the diet fed, both in pre-emergence and adult stages, along with age and sex of insect. Secondary responses to a gossypol-flucose incubate in the presence of emulsin, pH 8.0 phosphate buffer, or ATP, as well as sugars, salts, and ascorbic acid, were demonstrated. The insect-feeding threshold, determined from the straight-line plot of feeding activity vs. the log of extract concentration, was 0.015 mg.

393. ; Wiygul, G.; and Mitlin, N. 1967. Absorption and metabolism of C^{14}-labeled tepa by the boll weevil. J. Econ. Entomol. 60: 215-225.

Some aspects of the absorption and metabolism of C^{14}-labeled tepa by the male boll weevil, Anthonomus grandis Boheman, were studied. Topically applied tepa is absorbed almost immediately into the haemolymph, where it reaches a peak in 1-3 hours and then slowly declines. This trend parallels a decline of tepa on the cuticle to 10% within 6 hours. Values of the differential distribution ratio for body parts and organs were determined for injection and for topical treatment on the abdomen. Selective concentration occurred in the foregut, testes, and wings with injection and in the

wings only with topical treatment. Radioactivity detected in the spermathecae of females mated to treated males gave presumptive evidence that the sperm was labeled. About 85% of the initial radioactivity was detected in feces, expired CO_2, other expired volatiles, and body of injected insects after 2 days. Of the residual radioactivity in the body at 2 days, more than 85% was bound by constituents with low molecular weight.

394. ; Wiygul, G.; Vickers, D. H.; Bartlett, A. C.; and Mitlin, N. 1967. Sterility induced by tepa in the boll weevil: effective dose and permanency, gonadal changes, and biological turnover of labeled compound. J. Econ. Entomol. 60: 209-214.

The male boll weevil, Anthonomus grandis Boheman, was sterilized with tepa, either by feeding 1500 ppm in the diet for 2 days or by an injection of 3.5 μg. Lower levels produced transitory steriliztaion. At the effective levels, mortality was significant. A recovery of fertility occurred about 5 days after treatment at the 1.5-μg level. This recovery was less marked with an artificial diet than with cotton buds. In a study of single pairs 12 of 27 males, surviving treatment at the 1.0-μg level, regained fertility within 36 days. Decreases in the size of the testes and changes in morphology and cytology occurred. The radioactivity of insects treated with C^{14}-labeled tepa was decreased by half in 6-48 hours, depending on the diet, but 10-20% was retained for at least 10 days. No differences related to posttreatment diet were observed. Nitric acid was employed for digestion of insect tissue prior to C^{14} gas-flow counting. Conditions are described for reproducible and near-quantitative counting of the isotope.

395. Helms, W. F. 1973. 1971 boll weevil control program in the High Plains of Texas. Folia Entomol. Mex. 25-26: 74. (In Spanish, abstract only).

A Reproductive Diapause Control program was conducted again in 1971 in the High Plains and Rolling Plains of Texas. A major modification in the survey phase was assignment of an area of 60-75 fields to a survey team with each field checked once a week throughout the program. Previously, once a field was found infested, no further survey was conducted, as the field was automatically included in the program. Criteria for treatment of fields was established as follows: Prior to September 20, fields below the Caprock were treated when the punctured square count reached ten percent; and above the Caprock, five percent. After September 20, these criteria were increased to two percent and ten percent respectively. Fields with persistent populations above the criteria level were treated at least once a week. Populations in the control zone were very light in 1971. These light populations, plus the establishment of treatment criteria, greatly reduced the aggregate acreage treated. 379,544 acres were treated in 1971, as compared to 1,146,010 acres in 1970.

396. Henson, R. D.; Bull, D. L.; Ridgway, R. L.; and Ivie, G. W. 1976. Identification of the oxidative decomposition products of the boll weevil pheromone, grandlure, and the determination of the fate of grandlure in soil and water. J. Agric. Food Chem. 24: 228-231.

The oxidation products of grandlure were isolated by column and thin-layer chromatography. The compounds were identified by a combination of gas chromatography, mass spectrometry, ir, and proton magnetic resonance analysis. Two acids, two esters, and one aldehyde were identified as oxidation products of the grandlure aldehydes; the grandlure alcohols were stable. Soil and water persistence studies at 32 and 21°C showed that 98% of all components were lost from soil with 24 h at 32°C and that no grandlure remained

in soil after 32 h at either 32 or 21°C. Losses of grandlure from water were less rapid than soil; all components were dissipated from water within hours at 32°C. The physical barrier grandlure formulations currently in use showed no tendencies toward excessive soil and water contamination even under extreme conditions.

397. ; Thompson, A. C.; Gueldner, R. C.; and Hedin, P. A. 1971. Phospholipid composition of the boll weevil, Anthonomus grandis Boheman. Lipids 6: 352-355.

When phospholipids of newly-emerged adults of the boll weevil, Anthonomus grandis Boheman, were studied in detail, phosphatidyl choline and phosphatidyl ethanolamine were found to be the major phospholipids; sphingomyelin and cardiolipin were present in smaller amounts, and four other minor components were identified. Fatty acid analyses performed on the intact phospholipids and on the enzyme degradation products of phosphatidyl choline and phosphatidyl ethanolamine demonstrated that oleic and linoleic acids were the major fatty acids present in the glycerophosphatides; the sphingomyelin contained fatty acids in the range of 20-22 carbons.

398. ; Thompson, A. C.; Gueldner, R. C.; and Hedin, P. A. 1972. Constituents of the boll weevil. VII. The molting hormone: isolation studies. Ann. Entomol. Soc. Am. 65: 98-102.

The boll weevil molting hormone had the same behavior on TLC as 20-hydroxyecdysone and also showed the major absorption at 242 mμ which is characteristic of an α,β-unsaturated ketone chromaphore. The total HFU count for 1 kg of pupae was 1771. HFU requirements determined in our laboratory show that 1 HFU = 10-20 ng. Using this range of measurements, the amount of molting hormone in boll weevil pupae was calculated to be 17-35 μg/kg wet weight. The amount is low compared with that for other insects and suggests either a

unique trait of the boll weevil or that the maximum hormone titer occurs in a later stage in pupal development. However, this extremely low titer in 1-day-old boll weevil pupae will necessitate the collection of large quantities of insects for the isolation of sufficient material for structure determination.

399. ; Thompson, A. C.; Gueldner, R. C.; and Hedin, P. A. 1972. Variations in lipid content of the boll weevil during metamorphosis. J. Insect Physiol. 18: 161-167.

When neutral lipids and phospholipids of the boll weevil, Anthonomus grandis, were studied during the larval-pupal ecdysis, the volume of lipids was found to increase until the pupal stage when it underwent a small decrease. The opposite was true for the phospholipids. The neutral lipids were high in palmitic, palmitaleic, and oleic acids; the phospholipids had large amounts of stearic and linoleic acids. Also, the composition of the phospholipids was qualitatively similar in the larval, pharate pupal, and pupal stages though the larval stage was marked by a predominance of phosphatidyl ethanolarmine and a high concentration of linoleic acid in the phosphatidyl choline.

400. ; Thompson, A. C.; Gueldner, R. C.; and Hedin, P. A. 1974. Esterification of geraniol by homogenates of boll weevil. Ann. Entomol. Soc. Am. 67: 728.

The boll weevil possesses enzymes capable of esterifying geraniol with its normal fatty acids. The implications of this reaction are not clear at present since no information has been reported on reactions of this kind in natural systems. It is possible that these compounds are normal by-products of the terpenoid pathway in this insect. It may also be argued that these products are the result of a detoxication mechanism apart from intrinsic biological pathways. No evidence supporting either argument exists at present. However, further research at this laboratory may yield

information about the purpose of these unique compounds.

401. ; Thompson, A. C.; Gueldner, R. C.; and Hedin, P. A. 1975. Effect of a systemic juvenile hormone peptide analog on the developing boll weevil (Coleoptera: Curculionidae). J. Miss. Acad. Sci. XX: 40-41.

A systemic JHA could be extremely effective against the boll weevil, Anthonomus grandis Boheman, since the entire immature life of this insect is spent encased in the fruit of its host plant. Therefore, the boll weevil larva would not only feed on the JHA, but would also be in constant physical contact with the material. We conducted experiments to determine the concentrations of ethyl pivaloyl-L-alanyl-p-aminobenzoate required to alter development in immature boll weevils. The peptide was synthesized in our laboratory. The addition of 50 ppm of the peptide to the diet of the boll weevil larvae was sufficient to cause about 50% reduction in normal adult emergence; concentrations of 150, 200, and 250 ppm reduced normal adult emergence to less than 10%. Most insects reached the pupal stage successfully. However, after pupation, the development of treated insects seemed to halt, and the majority, especially at concentrations above 50 ppm, remained as live pupae for an extended period, but never molted to adults.

402. ; Vinson, S. B.; and Barfield, C. S. 1977. Ovipositional behavior of Bracon mellitor Say, a parasitoid of the boll weevil (Anthonomus grandis Boheman). III. Isolation and identification of natural releasers of ovipositor probing. J. Chem. Ecol. 3: 151-158.

The chemical cues in the frass of larvae of the boll weevil, Anthonomus grandis Boheman, that elicit an ovipositional response in females of Bracon mellitor Say were isolated by a combination of column, thin-layer, and gas-liquid chromatography. Derivatization, analytical tests, and mass spectrometry were used to identify the biologically active materials as long-chain fatty acid

esters of cholesterol. Bioassays with natural and synthetic cholesteryl esters were used to confirm activity. The activity of the cholesteryl esters was also confirmed by using females that had not been previously exposed to hosts.

403. Himel, C. M. 1969. The physics and biology of the control of cotton insect populations with insecticide sprays. J. Ga. Entomol. Soc. 4: 33-40.

The fluorescent particle spray droplet tracer method (FP method) is a new and valuable research tool which gives data on the physics and biology of insecticide spray droplet transport and impingement. The importance of the FP method lies in the fact that it can be used in the field in the actual environment of the target insect to determinethe actual number and size of spray droplets reaching the target (or non-target) insects and foliage. Over 100,000 droplets of spray material applied to a cotton field were identified by size and number on a total of 978 boll weevils, bollworms and cabbage loopers. In addition, cotton foliage and dissected cotton squares were examined in detail. Of the droplets found on the target insects, 99.4% were 40 μ or smaller and, of nearly 600 spray droplets that penetrated the squares, 95% were in the range of 20 μ. The mathematics and physics of the relation of spray droplet size to efficiency of application is discussed.

404. , and Moore, A. D. 1969. Spray droplet size in the control of spruce budworm, boll weevil, bollworm, and cabbage looper. J. Econ. Entomol. 62: 916-918.

The fluorescent particle spray droplet tracer method was used under field conditions to determine the size and number of spray droplets which impinged on spruce budworm, Choristoneura fumiferana (Clemens), in a Montana mountain forest and on the boll weevil, Anthonomus grandis Boheman; bollworm, Heliothis

zea (Boddie); and the cabbage looper, Trichoplusia ni (Hübner); in a Georgia cotton field. The data obtained reflect the physical, mathematical, biological and meteorological factors which determine transport to and impingement of the insecticide sprays on these insects in their widely diverse environments. A total of 101,495 spray droplets was identified by size and counted on 1324 insects. Eight droplets were identified in the 101-120 μ range; droplets less than 50 μ diameter constituted 99.7% of the total. The data show that the maximum diameter for efficient insecticide spray droplets is less than 50 μ. There is no evidence that spray droplets larger than 100 μ have any substantial efficiency in delivery of insecticide to these insects.

405. Hobbs, P. D., and Magnus, P. D. 1974. Synthesis of optically active grandisol. Chem. Commun. 21: 856-857.

This particular synthesis offers the possibility of preparing analogues via Wittig reactions on the lactol (III). The unusual photochemical transformation (XI) → (XII), generating the isopropenyl group and exposing the cyclobutane ring with the quaternary centre in the correct absolute configuration is a novel and quite general reaction for these particular pinane derivatives. All new compounds gave satisfactory spectral and microanalytical data.

406. ———, and Magnus, P. D. 1976. Studies on terpenes. 4. Synthesis of optically active grandisol, the boll weevil pheromone. J. Am. Chem. Soc. 98: 4594-4600.

(-)-β-Pinene was converted via the alcohol 26 into the ether 27 and, subsequently, the lactone 28. Reduction of the lactone 28 with lithium triethoxyaluminum hydride gave 6,9-dimethyl-8-hydroxy-7-oxatricyclo[4.3.0.$0^{3,9}$] nonane (29). Treatment of the lactol 29 with triphenylmethylenephosphorane gave the olefin 31 which was hydroborated using bis (3-methyl-2-butyl)borane followed by alkaline hydrogen peroxide to give the diol 33. Dehydration of

the primary monoacetate of the diol 33 gave a mixture of 9-acetoxymethyl-α- and β-pinenes (41 and 42). Oxidation of the mixture of 41 and 42 with chromium trioxide in pyridien gave the enone 44, which was hydrogenated to give 2αH-9-acetoxymethylpinan-4-one (45). Photolysis of 45 gave the aldehyde 46, containing approximately 10% of the cyclobutene 47. Decarbonylation of 46 using chlorotris (triphenylphosphine)rhodium gave grandisol acetate (1, R=Ac) (overall yield from (-)-β-pinene (3.5%)) which was converted into (+)-grandisol, (+)-(1R, 2S)-1-methyl-1-(2-hydroxy)ethyl-2-isopropenylcyclobutane.

407. Hollingsworth, J. P.; Witz, J. A.; Hartstack, A. W.; Lopez, J. D.; and Bull, D. L. 1978. Retention efficiency of the Leggett boll weevil trap. Southwest. Entomol. 3: 198-208.

Retention efficiency of the grandlure baited Leggett trap for the boll weevil, Anthonomus grandis Boheman, was determined with the assistance of electrical grids. Leggett traps mounted within energized electrical grids (LLG) were compared with Leggett traps mounted within unenergized grids (LDG) and with Leggett traps used in the conventional manner (L.). Traps LLG and L caught equal numbers of boll weevils during a season-long trial. Catches in the LDG trap were less than 1/3 as great as catches in the other trap types. There was no significant difference in response of males and females to the different trap types. Use of these trap catch data in trap performance equations showed that the retention efficiency of the Leggett trap was ca. 50%. This value was in agreement with data from observations in which only 1 weevil was trapped from each 2 weevils seen landing on the trap.

408. Hopkins, A. R., and Moore, R. F. 1980. Insecticides: efficacy against various cotton pests and effect on plant maturity, yield, and quality of seed and lint. J. Econ. Entomol. 73: 739-744.

Heliothis zea (Boddie), and H. virescens (F.) were controlled with foliar applications of the synthetic pyrethroids AC-222,705 (cyana(3-phenoxyphenyl) methyl (+)-4-(difluoromethoxy)-α-1-methylethyl)benzeneacetate), cis-permethrin, cypermethrin, NRCS-161 (S)-[cyano(3-phenoxyphenyl)mehtyl] cis-(+)-2-(2,2-dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate), fenvalerate, cis-cypermethrin, permethrin and the organophosphates, profenofos, sulprofos, and RH-0994 (O-[4-(4-chlorophenylthio)phenyl] O-ethyl S-propyl phosphorothioate), and the carbamate, thiodicarb. The cabbage looper, Trichoplusia ni (Hübner), was controlled with fenvalerate, profenofos, thiodicarb, and sulprofos + azinphosmethyl. The fall armyworm, Spodoptera frugiperda (J. E. Smith), was controlled with AC-222,705, and RH-0994 + azinphosmethyl. Light infestations of the spider mite, Tetranychus sp., was suppressed with RH-0994. Thiodicarb, profenofos, RH-0994, and sulprofos produced reddened leaves but had no apparent adverse effect on yield. Data from all tests indicated that the new material(s), per se, have no effect on maturity, germination of seed, fiber length, or fineness.

409. , and Moore, Raymond F. 1980. Thidiazuron: effect of applications on boll weevil and bollworm population densities, leaf abscission, and regrowth of the cotton plant. J. Econ. Entomol. 73: 768-770.

In a replicated field test with cotton, a preconditioning application of thidiazuron at 0.11 kg AI/ha followed by a full defoliating application (0.22 kg AI/ha) applied 7 days later removed significantly more leaves and squares and reduced regrowth significantly more than an application of a standard defoliant, S, S, S-tributyl phosphorotrithioate (as DEF®), applied at 1.56 kg AI/ha. Thidiazuron treatments also reduced population densities of boll weevils, Anthonomus grandis grandis Boheman, and bollworms, Heliothis zea (Boddie), but did not adversely affect yield, seed germination, or fiber properties.

410. ; Moore, R. F.; and Parencia, C. R. 1979. Cotton pests. In Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, Forests and Forest Products. U.S. Dep. Agric. Handb. 554, pp. 54-79.

This guide suggests use of chemicals and such related treatments as application of pathogens, heat and cold to control insects and related pests that affect crops, livestock, household and agricultural products in storage. This section concerns cotton insects. The information was compiled in consultation with the Pesticide Registration Division of the Environmental Protection Agency and the Extension and Cooperative Research staffs of the Science and Education Administration. These treatments are those recommended by the U.S. Department of Agriculture based on information obtained by the various Federal, State and other research organizations.

411. ; Moore, R. F.; and Parencia, C. R., Jr. 1980. Cotton pests. In Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, Households, Forests and Forest Products. U.S. Dept. Agric. Handb. 571, pp. 50-69.

This guide suggests use of chemicals and such related treatments as application of pathogens, heat and cold to control insects and related pests that affect crops, livestock, household and agricultural products in storage. This section concerns cotton insects. The information was compiled in consultation with the Pesticide Registration Division of the Environmental Protection Agency and the Extension and Cooperative Research staffs of the Science and Education Administration. These treatments are those recommended by the U.S. Department of Agriculture based on information obtained by the various Federal, State and other research organizations.

412. , and Taft, H. M. 1967. Control of cotton pests by aerial application of ultra-low-volume (undiluted) technical insecticides. J. Econ. Entomol. 60: 561-565.

In field tests conducted in 1965 with ultra-low-volume (undiluted) technical insecticides, malathion at 4-16 fluid oz per acre and Methyl Trithion® (S-[[p-chlorophenyl)-thio]methyl] O,O-dimethyl phosphorodithioate) at 6 or 12 fluid oz per acre applied in 50- or 75-foot swaths from fixed-wing aircraft controlled the boll weevil, Anthonomus grandis Boheman. Malathion at 12-16 fluid oz per acre applied in a 50-foot swath controlled a light infestation of the bollworm, Heliothis zea (Boddie), and suppressed populations of the cotton aphid, Aphis gossypii Glover, and the carmine spider mite, Tetranychus telarius (L.). However, it was less effective against these pests when it was applied in a 100-foot swath. Methyl Trithion applied at 6 or 12 fluid oz per acre in 50- or 75-foot swaths suppressed populations of cotton aphids and the carmine spider mite but gave poor control of the bollworm. In small-cage field tests, although malathion and Methyl Trithion were initially effective against the boll weevil, they were not effective longer than 48 hours.

413. , and Taft, H. M. 1968. Control of certain cotton pests with Union Carbide UC-21149. J. Econ. Entomol. 61: 736-739.

In-furrow treatments with Union Carbide UC-21149 (2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl)oxime, applied as Temik®, a 10% granular formulation, at 1 lb/acre at planting effectively controlled the boll weevil, Anthonomus grandis Boheman, until the plants began to square; as a side-dressing, it was as effective against the boll weevil as sprays of carbaryl and azinphosmethyl. Also, sidedressing with EC-21149 controlled light infestations of the two-spotted spider mite, Tetranychus urticae Koch, and the

cotton aphid, Aphis gossypii Glover. It was ineffective against the bollworm, Heliothis zea (Boddie), and the tobacco budworm, Heliothis virescens (F.). The toxicant did not adversely affect fruiting, germination, percentage of lint, seed index, or fiber quality.

414. ; Taft, H. M.; and Agee, H. R. 1971. Movement of the boll weevil into and out of a cotton field as determined by flight screens. Ann. Entomol. Soc. Am. 64: 254-257.

When the movement of Anthonomus grandis Boheman (Coleoptera: Curculionidae), into and out of a cotton field was monitored for 2 years with 3 x 5-ft flight screens, weevils were found to enter and leave the field throughout the season with the greatest numbers occurring during August and September. The numbers of weevils captured by the screens apparently reflect general activity, which is continuous throughout the season; however, peak numbers captured coincided with the emergence of generations. The numbers entering the field from other directions did so because of the favorable hibernation sites in that direction and an untreated cotton field beyond them. The flight screens were more efficient in monitoring weevils entering the field than those leaving it.

415. ; Taft, H. M.; and James, W. 1969. Life history of the boll weevil in field cages. J. Econ. Entomol. 62: 964-965.

A study was conducted to determine whether the number of boll weevil generations/season had changed since 1924-26 and to obtain more information about the reproductive potential of each generation. Each generation was started with marked weevils in cages containing 200 cotton plants. Each succeeding generation was produced by the 1st adults from the preceding generation. The preoviposition period ranged from 4 to 5.2 days and varied between years and among generations. The increase in population of each generation over the previous generation for the two years ranged 6-47 fold, overwintered; 16-20 fold, 2nd;

14-20 fold, 3rd; 4-7 fold, 4th; and 14 fold increase to 3 fold decrease, 5th.

416. ; Taft, H. M.; and James, W. 1975. Reference LD_{50} values for some insecticides against the boll weevil. J. Econ. Entomol. 68: 189-192.

The standard method (topical application) of determining resistance in Anthonomus grandis Boheman adopted by the Entomological Society of America was used to establish LD_{50} values for 6 experimental insecticides and 16 chemicals or chemical combinations. These values can serve as reference standards that may be used to detect changes in susceptibility. The average LD_{50}'s ranged from 0.052 μg/weevil for methyl parathion to 39,490 for carbaryl. Also, the LD_{50}'s obtained for toxaphene + DDT, methyl parathion, and carbaryl by the standard method were compared with the LC_{50}'s obtained with an immersion method and a dry film method. The dry film method appeared more promising for a field test kit.

417. ; Taft, H. M.; and James, W. 1977. Tobacco budworm, bollworm, and boll weevil: effectiveness of newly developed experimental insecticides on cotton in the Southeast. J. Econ. Entomol. 70: 723-726.

In replicated field tests permethrin (FMC-33297) (3-(phenoxyphenyl) methyl cis, trans-(±)-3-(2,2-dichloroethenyl), -2, 2-dimethylcyclopane-carboxylate, Shell SD-43775 (cyano(3-phenoxyphenyl) methyl 4-chloro-alpha- (1-methylethyl) (benzeneacetate), and Shell SD-41706 (cyano (3-phenoxy-phenyl) methyl 2, 2, 3, 3-tetramethylcyclopropane-carboxylate) gave outstanding control of the boll weevil, Anthonomus grandis Boheman, and the bollworm complex, Heliothis zea (Boddie) and H. virescens (F.). Bay NTN-9306 (O-ethyl[4-methylthio) phenyl] S-propyl phosphorodithioate) plus azinphosmethyl gave control equal to or better than the treated control, toxaphene + methyl parathion + chlordimeform. Rohm and Haas RH-218 (O-ethyl S-propyl O-2,4,6-trichlorophenyl) phosphorothioate) + toxaphene gave better control of Heliothis spp. than the treated control but produced low yields and was phytotoxic. In all tests, correlation analysis

showed that the means for boll weevil and Heliothis spp. infestation were negatively correlated with yield, and the highest yields were obtained when boll weevil infestations were held below the economic threshold level (10%) and when Heliothis spp. larval infestations in squares did not exceed 1.17± 0.17 SE larvae/100 squares. Numbers of live Heliothis spp. larvae/100 squares can be used readily to determine a treatment schedule that will give a sound pest management program.

418. ; Taft, H. M.; and James, W. 1979. Comparison of spray nozzles for ground applications for control of cotton insects and spider mites. J. Econ. Entomol. 72: 180-183.

Fenvalerate applied at a rate of 0.11 kg AI/ha to cotton gave equal control of the boll weevil, Anthonomus grandis grandis Boheman, Heliothis spp., beet armyworm, Spodoptera exigua (Hübner), fally armyworm, S. frugiperda (J. E. Smith), and cabbage looper, Trichoplusia ni (Hübner), whether the nozzles were the conventional type (Conejet TX6), the 8001 low-pressure fan nozzle, or Raindrop®, 33974-(3-23). Control of the carmine spider mite, Tetranychus cinnabarinus (Boisduval), with monocrotophos and American Cyanamid AC-85,258 (mitrilacard 1:1 complex with zinc chloride) applied with Raindrop 33974 (5-23) nozzles was statistically equal to that obtained with conventional nozzles. AC-85,258 was phytotoxic when applied with Raindrop 33974 (5-23) nozzles. An LD_{50} dose for the boll weevil was found at various distances downwind in relation to the type of spray nozzle used and height above plants. The only significant difference between the conventional and Raindrop nozzle 33974 (3-23) occurred when these were raised to 107 cm above the cotton plants.

419. ; Taft, H. M.; James, W.; and Jernigan, C. E. 1970. Evaluation of substitutes for DDT in field experiments for control of the bollworm and the boll weevil in cotton: 1967-69. J. Econ. Entomol. 63: 848-850.

Replicated field experiments of certain materials with and without DDT showed that methyl parathion, methyl parathion + DDT, toxaphene + methyl parathion, toxaphene + DDT, and azinphosmethyl + methyl parathion gave good control of the bollworm, Heliothis zea (Boddie), and the boll weevil, Anthonomus grandis Boheman, when weather was favorable and insecticide applications were made at short intervals. However, when rainfall was excessive and applications could not be applied at short intervals, methyl parathion, EPN (O-ethyl O-p-nitrophenyl phenylphosphonothioate), EPN + methyl parathion, and toxaphene + methyl parathion at the rates tested failed to give good control. In 2 experiments in which the differences in yield were statistically significant, formulations containing toxaphene + DDT + methyl parathion and toxaphene + DDT produced the highest yields, indicating that under prevailing weather conditions and bollworm population pressures in the southeast, use of materials with less residual activity will result in poorer control and lower yield.

420. ; Taft, H. M.; and Roach, S. H. 1977. Boll weevils: Leggett traps as a substitute for woods trash examinations as an indicator of potential field populations. J. Econ. Entomol. 70: 445-446.

During a 3-yr study, the number of emerging overwintered Anthonomus grandis Boheman captured in Leggett traps was positively correlated throughout the emergence period with the number of A. grandis found previously in samples of surface woods trash. Thus, the traps can detect a potential early field population on individual farms. This information will be useful in both pest management and eradication programs.

421. ; Taft, H. M.; Roach, S. H.; and James, W. 1972. Movement and survival of boll weevils in several hibernation environments. J. Econ. Entomol. 65: 82-85.

Anthonomus grandis Boheman obtained from surface woods trash in the fall were

rehibernated in 4 in. of woods trash which was dry (no moisture added), were moistened with the equivalent of normal rainfall (14.8 in.), or were wetted with 3-times normal rainfall. Numbers of surviving weevils that had remained in the trash where they were placed were significantly higher in trash treated with normal rainfall than in trash otherwise treated. However, 30% of the surviving weevils moved from their original locations, and significantly greater numbers moved to the dry trash or to trash treated with normal rainfall. Significantly greater survival occurred at the 1-in. depth in trash treated with normal rainfall than at any depth in the other 2 treatments. The overall recovery of weevils in this experiment was 48%.

422. House, V. S.; Ables, J. R.; Jones, S. L.; and Bull, D. L. 1978. Diflubenzuron for control of the boll weevil in unisolated cotton fields. J. Econ. Entomol. 71: 797-800.

In a 1976 test in unisolated cotton fields, different rates 35, 70, and 140 g AI/hs) of the insect growth regulator diflubenzuron, N-[[(4-chlorophenyl) amino]carbonyl]-2, 6-difluorobenzamide, were applied aerially over a 6-wk period to suppress populations of Anthonomus grandis Boheman. There was a pronounced dosage rate response to the chemical in that the percentage emergence of adult weevils from cotton squares collected from treated fields averaged 37.7, 22.2, and 15.8% at the lowest, median, and highest rate, respectively. Adult emergence from squares collected in untreated control plots averaged 70% during the same period. The reduction in weevil emergence was most pronounced in the F_1 generation and somewhat less in the F_2 and F_3 generations. A similar emergence pattern was observed in 1977 but due to a delay in the initial treatment the effect lagged by 1 generation. In both years, there was an apparent rebound by pest populations during the latter part of the season as indicated by increased emergence from the field collected squares. This result was attributed to movement of untreated

weevils into the treated fields.

423. ; Henson, R. D.; and Bull, D. L. 1978. Laboratory and field evaluations of selected synthetic pyrethroids for cotton insect control. Falia Entomol. Mex. 39-40: 66-67. (In Spanish, abstract only).

Tests were conducted in the laboratory and greenhouse to evaluate the effectiveness of several experimental synthetic pyrethroid insectides against the Cotton boll weevil, Anthonomus grandis Boheman, and the tobacco budworm, Heliothis virescens (F.). In addition, a late-season tests was conducted in small field plots to compare the effectiveness of oil (cotton-seed and mineral oil) formulations of FMC-33297 and a standard emulsifiable concentrate formulations of the chemical for control of natural populations of boll weevils. Results of these studies indicated the cottonseed oil formulation was most effective. These findings were supported by the results of laboratory and greenhouse experiments, which indicated that the inclusion of oil in a formulation increased uptake by boll weevils exposed to treated surfaces and increased both toxicity and residual activity of FMC-33297.

424. Huddleston, E. W.; Ashdown, D.; and Herzog, D. C. 1966. A comparison of the effects of the 1964 and 1965 High Plains Boll Weevil Control Program on population trends of non-target arthropods. Tex. Tech. Coll. Entomol. Rep. 66-1, 20 pp.

The High Plains Boll Weevil Control Program, initiated in the fall of 1964, was continued in the fall of 1965. Direct effects of the use of ULV Malathion on non-target arthropods were studied during and immediately after the conclusion of the 1964 program. In addition to an evaluation of the direct effects of the 1965 control operations, population trends of the indicator arthropods were followed throughout the 1965 growing season to determine the "carry-over" effects of the 1964 program of the preceeding fall. The indicator organisms

most severely affected were the lady beetle, Hippodamia convergens (Guer.); lace-winged flies, Chrysopa spp.; hooded beetles, Notoxus spp.; soft-winged flower beetles, Collops spp.; and scymnus beetles, Scymnus spp. of the new indicator groups added to the study in 1965, syrphid flies, family Syrphidae, order Diptera, and ichneumonid wasps, family Ichneumonidae, order Hymenoptera, were found to be highly susceptible to ULV Malathion. Spiders, also added in 1965, were not seriously depleted. As in 1964, the insects least affected were nabid bugs, Nabid spp.; big-eyed bugs, Geocoris spp.; and assassin bugs, family Reduviidae. Spring and summer populations of the indicator organisms did not appear to be adversely affected. In fact, populations of several of the indicator insects were larger in the control zone, treated in 1964, than outside the control zone where ULV Malathion had not been used.

425. ; Ashdown, D. and Hills, T. M. 1967. A comparison of the effects of the 1964, 1965 and 1966 High Plains Boll Weevil Control Programs on population trends of non-target arthropods. Tex. Tech. Coll. Entomol. Rep. 67-1, 14 pp.

The project for monitoring the High Plains Boll Weevil Control Program was designed to evaluate the effects of aerial application of ULV Malathion on certain non-target, terrestrial insects. Because of the favorable "balance of nature" that exists in cotton fields on the High Plains of Texas, special emphasis was placed on the effect of the control program upon the most important predators of those insects destructive to cotton. Overall results from the three years of this study show that the indicator species most adversely affected immediately following the application of ULV Malathion were: lady beetles, Scymnus beetles, hooded beetles, soft-winged flower beetles and lace-winged beetles. Those species whose populations were less seriously depleted by the direct effects of the control program were members of the order Hemiptera and included: nabid bugs, big-eyed bugs and assassin bugs.

Spiders, which were not further classified, did not appear to be too adversely affected by this spray program. Although the immediate effect of the control operations was of great importance, the most critical concern in this large scale program was the impact of the pesticide applications upon the populations of beneficial insects in the cotton fields during the following growing season. The results of this study show that there were no overall adverse effects of the use of these very late season applications of ULV Malathion on the beneficial insect populations in the following year. Due to the large areas covered and the lack of available personnel, it was impossible to critically evaluate the factors responsible for maintaining early and mid-season beneficial insect population at or above levels found in untreated areas.

426. ; Ashdown, D.; and Hills, T. M. 1967. Spring population trends of non-target insects following the third year of the High Plains Boll Weevil Control Program. Tex. Tech. Coll. Entomol. Rep. 67-2 (Suppl.), 10 pp.

The 1966 High Plains Boll Weevil Control Program appears to have had no major long term negative effects on the populations of beneficial insects present in the spring and early summer of 1967. In previous studies there were noted population increases in the spray zone above the caprock and population decreases in the spray zone below the caprock; however, the 1967 data indicate that there was also an apparent over-recovery of beneficial insects in non-cultivated areas below the caprock. Further studies should be conducted to revaluate the long range effects on non-target beneficial organisms, and the possibility of using such tools as out-of-season insecticide applications to reduce the need of in-season control practices.

427. ; Ward, C. R.; and Pully, J. L. 1968. Spring population trends of non-target insects following the fourth year of the High Plains Boll Weevil Control Program. Tex. Tech. Coll. Entomol. Rep. 68-2 (Suppl.), 12 pp.

The High Plains Boll Weevil Control Program of 1967 had no major adverse effect on the 1968 spring and early summer populations of beneficial insects found in non-cultivated land. In past years data from both cotton and pasture have indicated possible over-recovery in cotton in various areas in the control zones; however, the 1968 data from pasture only indicate no differences between the areas within the control zones and the untreated area. In 1967 special emphasis was placed upon a test evaluating the comparative effect of ultra-low volume Malathion and ultra-low volume Guthion on beneficial insects. In general, the effects of Malathion and Guthion upon the non-target insects were the same as the check and any apparent difference is probably due to experimental variation. Only one cotton sample was taken before the first of July due to the small size of the cotton. After further studies and statistical analysis of ample data, comparison of 1968 data with past data can be expected to yield more conclusive results.

428. Huddleston, P. M.; Mitchell, E. B.; and Wilson, N. M. 1977. Disruption of boll weevil communication. J. Econ. Entomol. 70: 83-85.

In laboratory tests conducted in Mississippi in 1975, boll weevils, Anthonomus grandis Boheman, were confused when the atmosphere was saturated with grandlure (I, (+)-cis-2-isopropenyl-1-methylcyclobutaneethanol; II, (Z)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol; III, (Z)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde; and IV, (E)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde). In field tests, grandlure did not cause confusion. Inhibition was indicated in field tests when the 2 aldehyde components were used alone.

429. Hudspeth, W. N.; Jenkins, J. N.; and Maxwell, F. G. 1969. Ascorbic acid impractical as a character for resistance in cotton to the boll weevil. J. Econ. Entomol. 62: 583-584.

The weight of adult Anthonomus grandis Boheman and the length of the developmental period were normal over 4 generations when adult and larval diets were formulated with 7.50-393.75 mg of ascorbic acid/100 g of diet. Approximately 500 adults were produced in each generation. When both diets were prepared without ascorbic acid only 10 adults were produced in the 2nd generation and none thereafter. No major effects on feeding or oviposition were found which could be associated with ascorbic acid content of the media. Since minute quantities of ascorbic acid are sufficient for the boll weevil, we concluded that it would not be practical to attempt to develop cotton lines resistant to the boll weevil via low ascorbic acid content.

I

430. Ivy, E. E. 1972. Pencap M: an improved methyl parathion formulation. J. Econ. Entomol. 65: 473-474.

Polymeric microcapsules containing methyl parathion have shown increased activity as well as longer residual action against Heliothis zea (Boddie), Anthonomus grandis Boheman, Tetranychus urticae Koch, Popillia japonica Newman, and Porthetria dispar (L.). In addition, the composition is no more than 1/500 as toxic by skin absorption, and 1/40 to 1/100 as toxic by ingestion than conventional methyl parathion formulation.

J

431. Jacobson, M. 1966. Chemical insect attractants and repellents. Annu. Rev. Entomol. 11: 403-422.

This review summarizes the main recent advances in the field of chemical attractants and repellents since 1960. Insects in which females and males produce sex attractants or excitants are listed.

432. James, P. E.; Hollingsworth, J. P.; Schoenleber, L. G.; and Glover, D., Jr. 1973. A mobile facility for rearing insects. J. Econ. Entomol. 66: 243-245.

An experimental mobile laboratory for insect rearing was designed and constructed to determine facilities for mass rearing of cotton insects, particularly the boll weevil, Anthonomus grandis Boheman. It was expected that this facility would serve as a model for larger-scale production units. Also, such small mobile units could serve as alternate facilities in case of equipment break-down or disease problems at major production facilities.

433. Jenkins, J. N. 1976. Boll weevil resistant cotton varieties. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 45-49.

Research in host plant resistance has been emphasized from the beginning at the Boll Weevil Research Laboratory (BWRL) in Mississippi. We have found a number of cotton lines with various degrees of boll weevil resistance. This report, however, concerns itself only with one character for resistance, Frego bract. From a genetic standpoint, this morphological trait is the easiest to work with of all the traits we have found. It is also the one that has the greatest potential at the present for near-immediate use in variety development. Though it has been tested more extensively than any-

thing else we have found, it is not the only source of boll weevil resistance with which we are working.

434. ; McCarty J. C., Jr.; Parrott, W. L.; Lindig, O. H.; and McLaughlin, R. E. 1972. Genetic characteristics of an ebony, pearl strain of boll weevil. J. Econ. Entomol. 65: 1611-1623.

A strain of Anthonomus grandis Boheman with 2 morphological mutants (ebony body color and pearl eyes) has been mass reared at the USDA Boll Weevil Research Laboratory. Ebony is controlled by a semidominant gene and pearl by a recessive gene. The strain was developed by individual pair matings of 75 ebony, pearl, laboratory culture females with 75 wild-type males obtained from southern Mississippi. In the F_2 ebony, pearl weevils were recovered. After 5.4 million insects (10.8 million gametes) were reared, a sample of 10,600 insects (21,200 gametes) was classified. The gene frequency of pearl was 1.0. The gene frequency of ebony was 0.00033e to 0.9967E. This should result in 1 weevil with wild-type body color in 10 million and all should have pearl eyes. The inability to diapause is under genetic control and was segregating in the F_2 generation from the original cross. After 5.4 million insects were reared (approximately 13 generations) the gene frequency was ca. 0.05d to 0.95D. Thus, the population had 2 very stable marker genes and was almost homozygous for inability to diapause, a dominant, lethal gene in nature.

435. ; McLaughlin, R. E.; Parrott, W. L.; and Wouters, C. J. J. 1970. Eliminating Glugea gasti (Protozoa: Microsporidia) from genetic stocks of the boll weevil. J. Econ. Entomol. 63: 1638-1639.

We eliminated the microsporidian Glugea gasti McLaughlin from genetic stocks of the boll weevil, Anthonomus grandis Boheman, capitalizing on the fact that the disease is not transmitted by males, although the gonads are infected. We crossed diseased, mutant males with healthy, wild-type females and recovered

the healthy mutants in the F_2 generation. Techniques designed to eliminate the disease and to insure recovery of healthy mutants in the F_2 generation were superimposed on the genetic procedure. The method is applicable to diseases of other insects in which one sex does not transmit the disease during mating.

436. ; Maxwell, F. G., and Parrott, W. L. 1967. Field evaluation of glanded and glandless cotton (Gossypium hirsutum L.) lines for boll weevil (Anthonomus grandis Boh.) susceptibility. Crop Sci. 7: 437-440.

The boll weevil is the major cotton insect in the rain-grown cotton belt. We investigated glandless cottons to determine if they were more susceptible to the boll weevil than the currently grown glanded varieties. Two years' results from large field plots with two pairs of glanded-glandless cottons indicated that the glandless genes gl_2 and gl_3 did not cause greater susceptibility in the Acala 4-42-77 and Rex Smoothleaf lines. Thirteen pairs of glanded-glandless lines were compared in small field plots. In each of the 13 comparisons no significant differences were found. Antibiosis tests showed slightly larger weevils on some glandless lines. These data suggest that the glandless character should not create increased boll weevil susceptibility, especially with careful selection of genetic background.

437. ; Maxwell, F. G.; Parrott, W. L.; and Buford, W. T. 1969. Resistance to boll weevil (Anthonomus grandis Boh.) oviposition in cotton. Crop Sci. 9: 369-372.

Cotton (Gossypium hirsutum L. and G. barbadense L.) lines were tested for 3 years in small field plots for boll weevil (Anthonomus grandis Boh.) resistance. A total of 23, 29, and 100 lines were evaluated at one location in 1965, 1966, and 1967 respectively. Five frego, four red, and several Sea Island cotton lines received less boll weevil oviposition than the commercial check line. Oviposition

under these field conditions may have measured a different component of preference than our standard laboratory test for oviposition factors. In general, however, lines selected in our laboratory test for low oviposition also showed reduced oviposition in the field tests. A covariance analysis adjusted the number of oviposition damaged squares for the number of oviposition damaged squares for the number available to the weevil for oviposition. Gains in precision ranged from 49 to 105% from the use of covariance.

439. , and Parrott, W. L. 1971. Effectiveness of frego bract as a boll weevil resistance character in cotton. Crop Sci. 11: 739-743.

In 1970 four farms located in different parts of Mississippi each were planted to 4 to 8 ha of cotton (Gossypium hirsutum L.), homozygous for frego bract (fg fg), and to an approximately equivalent acreage of a non-frego commercial variety. Cottons with frego bract have shown resistance to boll weevils (Anthonomus grandis Boh.) when grown in small plots. Our 1970 tests were designed to measure the cumulative effects of a frego-bract cotton, designated M-64, on boll weevil populations when this cotton was grown in large acreages and when the resistance was measured over three or four insect generations. Results from these tests will be used to assess the role of cottons resistant to boll weevil in an integrated approach designed to eradicate this insect. A pilot scale boll weevil eradication program is now underway in Mississippi. In the frego-bract cotton boll weevil oviposition, an indirect measure of population, was suppressed 66, 71, 75, and 94% below that in the nonfrego varieties. The variation in suppression was due to different numbers of overwintering weevils and to various control measures used during the season. On two farms no insecticides were required for boll weevil control in the frego-bract strain. The frego-bract strain suppressed the population 94% on the farm with the smallest number of overwintering weevils. Thus, oviposition suppression was greatest where it can be of the most use in an eradication program. Fiber properties

and yields of the frego strain were adequate for a nonbiased test of the boll weevil resistance attributed to frego bract.

439. ; Parrott, W. L.; and Jones, J. W. 1975. Boll weevil oviposition behavior: multiple punctured squares. Environ. Entomol. 4: 861-867.

We hypothesized that the ♀ boll weevil, Anthonomus grandis Boheman, does not discriminate against squares in which an egg has previously been oviposited. We call this the non-discrimination hypothesis. The objective of this study was to compare the observed distribution of single and multiple eggs/square over a range of infestation levels (0-100%) with theoretical values based on our hypothesis. We observed 28,750 squares and classified 22,526 oviposition punctures in yr 1 and 6500 squares and 3549 oviposition punctures in yr 2. Our data support the non-discrimination hypothesis - the ♀ boll weevil did not detect squares containing an egg and did not discriminate against squares containing an egg. Large samples such as these allow a statistical approach to an understanding of some aspects of insect behavior that can not be obtained from observations of a small sample or of a small number of samples.

440. ; Parrott, W. L.; and McCarty, J. C., Jr. 1973. The role of a boll weevil resistant cotton in pest management research. J. Environ. Qual. 2: 337-340.

The role of the boll weevil (Anthonomus grandis Boh.) resistant cotton (Gossypium hirsutum L.) strain, frego bract, in the management of cotton pests was investigated in 22 fields in Yalobusha County, Mississippi in 1971. The objectives were (i) to measure the boll weevil population suppression when frego bract cotton was used with and without a reproduction-diapause program the previous year, and (ii) to determine if the resistant cotton strain could materially aid in removing the boll weevil as the key pest in cotton fields. If so, one could potentially use integrated control for other cotton pests and also con-

duct research on pest management systems. The use of the frego cotton suppressed the boll weevil population 69% and 79%, respectively, with and without a diapause program. In addition, the beginning of weekly applications of insecticides for boll weevils was delayed 4 weeks longer in the frego fields than in nonfrego fields. We were able to go through the period of peak activity of the bollworm complex (Heliothis spp.) before we needed boll weevil insecticides in the frego. However, in the non-frego fields we were applying boll weevil insecticides in the frego. However, in the non-frego fields we we were applying boll weevil insecticides before and during this time. Thus, frego can be used in research on pest management systems while it continues to be tested for use as a resistance character for commercial varieties.

441. Jernigan, J. E. 1976. Extension and information roles in boll weevil elimination. In Boll Weevil Suppression, Management, and Elimination Technology: Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 161-162.

Experience gained in the Pilot Boll Weevil Eradication Experiment showed that cooperation among the many agencies needed in carrying out this project is possible and obtainable. Monthly meeting of personnel from each agency proved to be an invaluable source of communication while the project was in operation. Such a plan would, no doubt, serve the best interest of any future elimination project. Extension administrators in the States involved recognize the role Extension must play in such a project, and they have indicated a genuine interest in cooperating to the extent that resources are available in the first phase of the program in 1974. To begin the program, a committee of Extension and industry leaders in each State will review the proposal, decide what is needed in their local area, and set the plan in action during the spring of 1974. If funds are made available for the elimination project, Extension would then assume responsibility for conducting its educational role in the second phase of the program

to the extent that resources allow.

442. Johnson, E. K.; Young, J. H.; Molnar, D. R.; and Morrison, R. D. 1976. Effects of three insect control schemes on populations of cotton insects and spiders, fruit damage, and yield of Westburn 70 cotton. Environ. Entomol. 5: 508-510.

Numbers of predatory insects (lady beetles, primarily Hippodamia spp.; green lacewings, Chrysopa spp.; nabids, Nabis spp.; soft-winged flower beetles, Collops spp.; hooded beetles, Notoxus monodon F.; big-eyed bugs, Georcoris spp.), spiders (unidentified), and fleahoppers, Pseudatomoscelis seriatus (Reuter) were determined weekly in cotton grown under 3 insect control schemes. Numbers of fruits damaged by the Heliothis complex (the bollworm, Heliothis zea (Boddie), and the tobacco budworm, H. virescens F.) and by the boll weevil, Anthonomus grandis Boheman were also determined. The 3 control schemes used were (1) strip-planted with grain sorghum, (2) solid-planted, insecticide treatments according to OSU Agriculture Extension Service recommendations, and (3) solid-planted, no insecticide treatments. Significantly greater numbers of predators occurred in the strip-planted plots. Overall differences in fleahopper numbers and fruit damage by the Heliothis complex were insignificant. Damage by the boll weevil was negligible. Yield per acre in the strip-planted test was higher at P=0.10 than in either of the other tests. In addition, an avg. 5308 lbs/acre of grain sorghum was produced in the strip planted plots.

443. Johnson, W. L. 1980. Marking of boll weevils inside cotton squares with Calco Oil Red N-1700. J. Econ. Entomol. 73: 664.

Boll weevils, Anthonomus grandis grandis Boheman, were marked in growing cotton without any manual or mechanical manipulation of the insect by injecting Calco Oil Red N-1700® dye into the square with a syringe. After 21 days as an adult,

199 of 203 marked boll weevils contained enough dye to be seen readily under the integument of the abdomen. The 4 boll weevils not detected by the visual examination were found to be marked after being crushed and placed in a small vial containing acetone and a strip of filter paper.

444. ; Cross, W. H.; Leggett, J. E.; McGovern, W. L.; Mitchell, H. C.; and Mitchell, E. B. 1975. Dispersal of marked boll weevil: 1970-1973 studies. Ann. Entomol. Soc. Am. 68: 1018-1022.

Dispersal of the boll weevil, Anthonomus grandis Boheman, was studied in Mississippi from 1970 through 1973 by releasing marked adults in central fields planted to cotton and locating traps at various distances and directions. The maximum distances sampled were 10.4 miles in 1970, 24 miles in 1971 and 50 miles in 1972 and 1973. Of the total of 383,061 native boll weevils marked and released, 265 were recaptured at distances from the release site of from 1 to 33 miles. Marked weevils were recaptured at the maximum distances sampled in 1970 and 1971. The longest distance, 33 miles, was recorded during the 1973 study.

445. ; Cross, W. H.; and McGovern, W. L. 1976. Long-range dispersal of marked boll weevils in Mississippi during 1974. Ann. Entomol. Soc. Am. 69: 421-422.

In a study of long-range dispersal of the boll weevil, Anthonomus grandis Boheman, in Mississippi in 1974, 162,028 marked adults were released in the center of a trap grid. Eighty-six were captured in traps located on concentric circles at 5-mi intervals for a distance of 50 miles. Two boll weevils were captured at a distance of 45 miles. This is the longest recorded for marked boll weevils; it equals the distance recorded for an unmarked boll weevil in Mexico.

446. ; Cross, W. H.; McGovern, W. L.; and Mitchell, H. C. 1973. Biology of Heterolaccus grandis in a laboratory culture and its potential as an introduced parasite of the boll weevil in the United States. Environ. Entomol. 2: 112-118.

Heterolaccus grandis Burks parasitizes the 3rd instar of Anthonomus grandis Boheman in parts of Costa Rica, Nicaragua, Guatemala, and Mexico. It has been described as a primary parasite of this pest. In the laboratory, the developmental period was 15-17 days for males and 17-18 days for females at 24-27°C and 45±2% RH. The incubation period for the egg was 27-29 hours. The larvae, which were cannibalistic, have 3 stadia and a larval period of 4.5-5.5 days. The pupal stage was 6-7 days for males and 8 days for females. Oviposition began 3-4 days after adult eclosion. Females deposited an average 6.38 eggs per day, an average total of 315 eggs per female. Average longevity was 51.2 days for males and 65.0 days for females. The culture of H. grandis from Mexico gave no evidence of overwintering. After initial release in the field, percentages of parasitism of boll weevils by H. grandis increased progressively during the season.

447. ; McKibben, G. H.; Rodriguez, J. V.; Davich, T. B. 1976. Boll weevil: increased longevity of grandlure using different formulations and dispensers. J. Econ. Entomol. 69: 263-265.

An experimental slow-release formulation of grandlure, the synthesized pheromone of Anthonomus grandis Boheman, was as effective or more effective for 8 wk than the standard formulation changed weekly.

448. ; Moody, D. S.; Lloyd, E. P.; and Taft, H. M. 1978. Boll weevil: egg hatch inhibition with four formulations of diflubenzuron. J. Econ. Entomol. 71: 179-180.

Four formulations of diflubenzuron containing 141.8 g AI/ha (25% WP in cotton

seed oil; 39.8% flowable in Savol®; 25% WP in Savol and water; and 25% WP in Sun Oil 7N® and water) were applied by plane to 2-ha replicated plots of cotton in Mexico for control of Anthonomus grandis Boheman. All treatments were significantly different from the check and were highly effective in inhibiting boll weevil egg hatch. These were no significant differences in effectiveness among treatments.

449. Joiner, R. L., and Lambremont, E. N. 1969. Hydrocarbon metabolism in insects: oxidation of hexadecane-1-^{14}C in the boll weevil and the house fly. Ann. Entomol. Soc. Am. 62: 891-894.

The boll weevil, Anthonomus grandis Boheman, and the house fly, Musca domestica L., metabolized injected hexadecane-1-^{14}C. Two metabolic products were isolated, $^{14}CO_2$ and fatty acids. When hexadecane was administered by injection, a characteristic release pattern of $^{14}CO_2$ was noted which included an initial peak of $^{14}CO_2$ output. This peak was followed by a lag period then by a 2nd peak of production. Hexadecane-1-^{14}C also was given to the boll weevil in its diet and was converted to labeled fatty acids. The principal labeled fatty aicds found contained 16 carbon atoms, suggesting direct conversion of hexadecane to fatty acid by terminal oxidation. C16:0 predominated in the boll weevil, and C16:1 in the house fly, but radioactivity was also found in C18:0 and C18:1 fatty acids. The fatty acids were distributed to triglycerides, phospholipids, sterol esters, and to other fatty acid-containing lipid fractions.

450. Jones, D., and Sterling, W. L. 1978. Locomotory activity and distribution of overwintering boll weevils in east Texas leaf litter. Southwest. Entomol. 3: 315-321.

Boll weevils, Anthonomus grandis Boheman, were reared under natural environmental conditions of food, temperature, and photoperiod during the fall. More weevils

emerging from fruit after early December exhibited locomotory activity during warm winter days than weevils emerging during October or November. Activity during mid-winter exposes weevils to environmental extremes not occurring in protected overwintering sites, and thus may be detrimental. Distribution studies of boll weevils in leaf litter indicated no relationship between time of emergence from fruit during the fall and vertical distribution in leaf litter. More weevils were found in the upper 5.1 cm of litter than in underlying litter.

451. , and Sterling, W. L. 1979. Manipulation of red imported fire ants in a trap crop for boll weevil suppression. Environ. Entomol. 8: 1073-1077.

Red imported fire ants were introduced into an early-planted East Texas cotton plot, while ants were essentially removed from a control plot with Mirex. In the ant plot, predation by ants reduced the number of emerging F_1 weevil adults, and weevil damaged squares never exceeded 16.6% through June and early July. During this time incidence of weevil damaged squares in the Mirex plot increased to 38.8%.

452. , and Sterling, W. L. 1979. Rate and thresholds of boll weevil locomotory activity in response to temperature. Environ. Entomol. 8: 874-878.

Boll weevils collected from pheromone traps and newly eclosed adults were tested for locomotory activity at various temperature and light-dark conditions. Greater flight activity was observed during the light than dark cycle for pheromone trapped and boll reared weevils. Light-dark conditions did not appear to affect walking activity. Temperature thresholds for flight and walking averaged 14.0° and 2.6°C, respectively.

453. , and Sterling, W. L. 1979. Temperature thresholds for spring emergence and flight of the boll weevil. Environ. Entomol. 8: 1118-1122.

A strong relationship was found between temperature and emergence of boll weevils from overwintering sites. The threshold temperature above which overwintering weevils accumulated heat units was 10.85° ± 1.3°C. Early fall cohorts required a higher number of accumulated heat units than did late fall cohorts. First-emerging weevils of early cohorts had a lower tendency to subsequently initiate flight activity than did first-emerging weevils of later cohorts. The temperature threshold for flight of 95-98% of newly emerging weevils was 20°C.

454. Jones, J. E.; Weaver, J. B., Jr.; and Schuster, M. F. 1978. Host plant resistance of the boll weevil. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 50-73.

Host plant resistance to the boll weevil is available in several cotton genotypes. Furthermore, several of the resistant characteristics have been transferred successfully into agronomically desirable cottons. The commerical use of these cottons is now largely a matter of integrating them into appropriate pest management schemes. Frego Bract, redleaf and red stem, and okra leaf and super-okra leaf are available resistance traits. Male sterility and reduced anther numbers are traits that hold considerably promise of seriously disrupting the biology of the boll weevil. These traits as well as the boll weevil oviposition-suppression factors present in some G. hirsutum race stocks and G. barbadense strains, must be considered as traits of potential value at this time, since each will require additional breeding and testing studies to fully determine its potential usefulness in boll weevil management programs.

455. Jones, J. W.; Bowen, H. D.; Stinner, R. E.; Bradley, J. R., Jr.; and Bacheler, J. S. 1977. Simulation of boll weevil population as influenced

by weather, crop status and management practices. Trans. ASAE 20: 121-125, 131.

A model is presented here for the population dynamics of the boll weevil. Each component of the equations developed is described separately, and the mathematical analysis is tied together with biological reality.

456. ; Bowen, H. D.; Stinner, R. E.; Bradley, J. R., Jr.; Sowell, R. S.; and Bacheler, J. S. 1975. Female boll weevil oviposition and feeding processes: a simulation model. Environ. Entomol. 4: 815-821.

A model is presented for predicting the number of cotton fruit damaged per day by reproducing female boll weevils, Anthonomus grandis Boheman. The model separately considers the egg production and the oviposition process of the female boll weevil. The oviposition process depends on the availability of eggs in the oviducts, preferential site selection, and the availablity of sites. Components of behavior for individual female boll weevils are considered and expected crop damage is projected for population of insects. Data are presented and compared with simulated results and the sensitivity of the model to changes in pertinent parameters is discussed.

457. ; Lloyd, E. P.; and Stinner, R. E. 1977. Insect population mortality: a dynamic model of insecticide effectiveness. Environ. Entomol. 6: 799-803.

The study of insect-pest management systems requires knowledge of the effectiveness of applied insecticides. The study reported here was conducted to develop a method to estimate insecticide induced mortality of an insect population depending on the rate of application, the persistence of the insecticide, a dosage-mortality relationship, and the time of exposure of the insects to a treated area. A logarithmic equation was developed to estimate the cumulative percent mortality with time. The model was validated using mortality data for

boll weevils, Anthonomus grandis Boheman, exposed to 2 rates of each of azinphosmethyl and methyl parathion. The method developed in this paper can be used to study insect population dynamics as affected by the timing and rates of insecticide applications, increasing insect resistance to insecticides, and the use of different insecticides.

458. ; Smith, D. B.; Colwick, R. F.; and Scott, W. P. 1971. Computer studies involving boll weevil damage to cotton. Miss. Agric. For. Exp. Stn. Inf. Sheet 1161, 4 pp.

Insect control continues to be one of the major economic problems of the cotton farmer. This study involves efforts to predict how much damage is caused to the squares of the cotton plant by boll weevil populations and how the damage to the squares will ultimately affect yield. It was found that the plant tends to adjust to insect damage and if allowed enough good weather, it will produce as much as an undamaged plant. Predictions of actual pounds of lost yield should provide better information for more efficient insect control programs to maximize the producer's profits and keep pollution potential to a minimum.

459. ; Thompson, A. C.; and McKinion, J. M. 1975. Developing a computer model with various control methods for eradication of boll weevils. Proc. 1975 Beltwide Cotton Prod. Res. Conf., p. 118.

In May, 1974 ARS personnel of the Boll Weevil Research Laboratory (BWRL) and the Cotton Production Research Unit, at Mississippi State, Mississippi, cooperated jointly and assembled information to develop a descriptive model for boll weevil eradication. This model was to be used to help identify critical research needs and to study synchronization of components of insect suppression measures. Three submodels evolved from this effort--pheromone trapping, sterile insect release, and insecticide effectiveness--are in various stages of testing.

460. Jones, S. E., and Parencia, C. R. 1968. Research - Behind the scenes with USDA. Cotton (Sept.): 18, 22-23, 25.

The complexity and significance of the cotton insect situation has been reviewed and the research program briefly discussed. With modest increases in appropriations, it has been possible to initiate much needed basic research. Discoveries recently made and others yet to come may be expected to provide new less expensive methods for controlling cotton insects and thus lowering production costs.

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461. Keever, D. W., Bradley, J. R. Jr. and Ganyard, M. C. 1977. Effects of diflubenzuron (Dimilin) on selected beneficial arthropods in cotton fields. Environ. Entomol. 6: 732-736.

Populations of the arthropod predators, Geocoris punctipes (Say), Nabis spp., Hippodamia convergens Guerin, Coleomegilla maculata (DeGeer), Orius insidiosus (Say), Chrysopa spp., and Araneida, were monitored in cotton fields treated with diflubenzuron, in cotton fields treated with conventional insecticides, and in cotton fields to which no insecticides were applied. G. punctipes and H. convergens were taken from both diflubenzuron-treated and untreated fields to the laboratory to study oviposition and egg hatch. With the exception of G. punctipes, reduction of predator populations in diflubenzuron-treated fields vs. untreated fields was not significant. This was in marked contrast to the highly adverse effects of conventional insecticides upon the predator populations. For 6 days after collection, egg hatch in laboratory-held H. convergens was significantly lower in females collected from diflubenzuron-treated cotton fields than in those from untreated fields. Additional differences in fecundity were not detected in the laboratory studies.

462. King, E. E. 1972. Pectinases from boll weevil larvae, Anthonomus grandis. J. Insect Physiol. 18: 1295-1301.

Assays were conducted throughout a wide pH range to measure the ability of extracts from third instar boll weevil larvae to degrade pectic substances. Pectin was deesterified and was depolymerized by both hydrolytic and trans-eliminative mechanisms. Sodium polypectate (deesterified pection, or pectic acid) was depolymerized solely by trans-elimination. Addition of Ca^{2+} failed to stimulate the trans-eliminative cleavage of either pectin or polypectate. It is possible that one or more of the pectinases from boll weevil larvae contribute to the abscission of infested cotton flower buds.

463. . 1973. Endo-polymethylgalacturonase of boll weevil larvae, Anthonomus grandis: an initiator of cotton flower bud abscission. J. Insect Physiol. 19: 2433-2437.

Pectinases of boll weevil larvae were fractionated by gel filtration, $(NH_4)_2SO_4$ precipitation, and hydroxylapatite chromatography. A fraction rich in endo-polymethylgalacturonase (endo-PMG) was able to macerate anther tissue and initiate abscission when injected into cotton flower buds. By partially destroying the cuticular permeability barrier, ethyl acetate and other solvents enhanced the abscission-initiating ability of the enzyme fraction. Growth regulator imbalances and degradation products resulting from endo-PMG action are probably the ultimate causal agents of abscission in flower buds.

464. , and Lane, H. C. 1969. Abscission of cotton flower buds and petioles caused by protein from boll weevil larvae. Plant Physiol. 44: 903-906.

Protein extracted from boll weevil larvae causes abscission of cotton flower buds and debladed petioles. Abscission of buds is preceded by a rapid and persistent flaring of bracts; cell proliferation is induced in the abscission zone of debladed petioles. A possible mode of transmission of the agent from

larva to bud tissue is discussed.

465. Kirk, I. W., and Bottrell, D. G. 1969. A mechanical sampler for estimating boll weevil populations. J. Econ. Entomol. 62: 1250-1251.

Many cotton fields must be surveyed thoroughly to evaluate effectiveness of the High Plains reproductive-diapause boll weevil, Anthonomus grandis Boheman, control program. To meet this need, a tractor-mounted machine was constructed for evaluation in the reproductive-diapause control zone. The design of the experimental machine was similar in principle to that of the commercial Nisbet insect-collecting machine sold as a control device throughout the cotton belt in the 1940's. The machine produced an air stream across a row of plants to dislodge insects into a collection bag. Sampling of boll weevil populations with mechanical methods described here reduced the labor requirements for population estimates by 90%. This machine, with further adaptation and development, has the potential for obtaining reliable boll weevil population estimates quickly and inexpensively.

466. Kirk, V. M., and Taft, H. H., Jr. 1970. Beetles found in woods trash during winter boll weevil surveys. U.S. Dep. Agric. Prod. Res. Rep. 119, 12 pp.

Samples of woods trash collected in the fall and spring in South Carolina were examined to determine the numbers of boll weevils (Anthonomus grandis Boheman) entering hibernation sites and surviving the winter. The material was also examined for all other species of beetles. Of 405 species found, representing 41 families of beetles, 35 species are well-known pests. Many others are from families that include serious pests. Twenty-one species of lady beetles (Coccinellidae) and over 100 species from families that are mostly predators on other insects were identified.

467. Klassen, W. 1976. Research requirements for boll weevil elimination in the Cotton Belt. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 163-166.

In the interest of developing a research game-plan which will allow us to attend to the most critical needs in the shortest possible time, and yet not dampen opportunities for important ancillary achievements, I have fearlessly divided the research needs into three categories. Doubtless some of my colleagues will take exception to my placement of one or more of their projects. I invite such scientists to try to persaude me to change my mind. In setting priorities for boll weevil research, it seems helpful to divide the research objectives into three categories, or arrays. The first is the critical array which includes only those research objectives which are absolutely essential to obtain major new improvements in the reliability and economy of the boll weevil suppressive system. The second group of research objectives is the concurrent array. Achievement of objectives in the concurrent array seems fairly certain, and although such accomplishments are not absolutely essential, they would be very helpful in further increasing the reliability and economy of the suppressive system. The third group of research objectives is the supplementary array. The supplementary array contains high-risk objectives as well as those which may or may not prove to be important or needed. These high-risk objectives could result in substantial improvements, but we dare not rely on their accomplishment at this time.

468. , and Earle, N. W. 1970. Permanent sterility induced in boll weevils with busulfan without reducing production of pheromone. J. Econ. Entomol. 63: 1196-1198.

When busulfan (1,4-butanediol dimethanesulfonate) was fed to adult *Anthonomus grandis* Boheman for 6 days as 0.1% of the diet, it induced greater than 99%

sterility in all males and permanent sterility in 97% of the males, and it drastically reduced the fecundity of females. The cumulative mortality at 3 weeks posttreatment was moderate. In at least 4 consecutive matings, each treated male displaced normal sperm in a previously mated female. The production of pheromone by treated males was normal.

469. ; Knipling, E. F.; and McGuire, J. U., Jr. 1970. The potential for insect-population suppression by dominant conditional lethal traits. Ann. Entomol. Soc. Am. 63: 238-255.

Calculations are presented to show the possibility of suppressing insect populations by overflooding a native population with individuals bearing dominant conditional lethal traits. If a conditional lethal trait is determined by a single dominant factor fully penetrant in the heterozygotes, then a native population of 100 insects per acre could be eradicated by 3 releases of 12 mutants for every insect in the native population. Comparable results would be achieved with a polyfactorial conditional lethal trait if the hybrids differed from the native population. Since inability to diapause is considered to be an ideal conditional lethal trait for control, hypothetical population models were worked out to determine the impact of releasing boll weevils, Anthonomus grandis Boheman, carrying an assumed dominant nondiapause trait. If a natural population were reduced by a special schedule of treatments with insecticides to 1 male and 1 female per acre and then overflooded by a factor of 99 of each sex, all carrying the dominant conditional lethal trait, the overwintering population (F_4 generation) would be reduced by 99.99%. This reduction would constitute practical eradication. An alternate procedure involving the use of a similar nondiapausing strain that was partially sterilized by irradiation or chemosterilants would avoid economic damage to cotton pending the final eradication of the pest by the conditional lethal trait.

In this hypothetical model, a small natural population would be initially overflooded 99:1, and such releases would be continued for 4 generations. The natural population would be effectively suppressed by sterility while the dominant conditional lethal genes were being introduced into the natural population often enough to assure extnction of the population during the winter. The estimated costs show that it will be entirely practical to use these genetic methods for eradication if they can be perfected.

470. , and Norland, J. F. 1967. Sterilization of the boll weevil. Proc. N.C. Branch Entomol. Soc. Am. 22: 140.

When fed to male weevils for three days methane sulfonic acid, tetramethylene ester induced sexual sterility with little mortality. Several aziridinyl compounds induced a high degree of sterility, however some mortality supervened. Certain structure-activity relationships are detailed.

471. ; Norland, J. F.; and Borkovec, A. B. 1968. Potential chemosterilants for boll weevils. J. Econ. Entomol. 61: 401-407.

Methanesulfonates, nitrogen mustards, aziridines, phosphoramides, s-triazines, and miscellaneous chemicals were evaluated for chemosterilant activity by feeding them to male boll weevils, Anthonomus grandis Boheman. Sterility without mortality was induced by busulfan (ENT 25012) (1,4-butanediol, dimethanesulfonate); ENT 51904 (1,3-propanediol, dimethanesulfonate), chlorambucil (ENT 26083) (4(p-[bis(2-chloroethyl)amino]phenyl)-butyric acid); ENT 51007 (N,N,N',N'-tetramethyl-p-piperidino-phosphonic diamide); and several aziridines, the most promising being the cyclic diester of pentaerythritol and I-aziridinylphosphonic acid.

472. ; Norland, J. F.; and Briggs, R. W. 1969. Sterilization of boll weevils with combinations of chemosterilants and X-rays, gamma rays, thermal neutrons, or fast neutrons. J. Econ. Entomol. 62: 1204-1216.

This study was undertaken to determine whether satisfactory sterility without

mortality could be induced in Anthonomus grandis Boheman. Adult boll weevils irradiated with 2.5 krad of X-rays and immersed in a 1.0% solution of apholate within 8 hours had a greater cumulative percentage mortality at 3 weeks than when the 2 treatments were separated by several days. However, the treatments failed to destroy completely the germarium in all males. Destruction of the germarium occurred more frequently if the males were still soft bodied when they were immersed. Thus, when 2-day-old males were immersed in apholate and X-irradiated 80 hours later, the majority sustained permanent destruction of the germarium. Weevils treated with 2.5 krad of γ-rays and a 1.0% solution of apholate reestablished the spermatogenic cycle as early as 13 days later and usually within 3 weeks; in 1 test, recovery of fertility occurred 11-13 days after treatment, and in 2 other tests, recovery occurred at 14-16 days after treatment. Sublethal doses of thermal neutrons did not sterilize boll weevils, but 1 krad of fast neutrons significantly reduced the fertility of treated males and the fecundity of treated females. Doses of fast neutrons greater than 1.2 krad caused high mortality, but a dose of 2 krad was necessary to sterilize all sperm and destroy all spermatogonia. Fecundity of treated females was greatly reduced with 1.5 and 2 krad. However, their fertility was depressed only moderately. Irradiation of either sex with 1 krad of fast neutrons and immersion 3 days later in a 1.0% solution of apholate resulted in almost complete sterility, though the spermatogenic cycle was re-established in some individuals at 4 weeks after treatment. Moreover, this treatment reduced mating competitiveness of males treated as adults less than treatment with 2.5 krad γ-rays and a 1.0% solution of apholate.

473. Knipling, E. F. 1966. Population models to test theoretical effects of sex attractants used for insect control. U.S. Dep. Agric. Inf. Bull. 308, 20 pp.

Entomologists have shown that males of many insect species will contact or

come within the vicinity of cages containing virgin females of the same species (or extracts containing pheromones of these females). This behavior has been demonstrated for such insects as the gypsy moth [Porthetria dispar (L.)], European pine sawfly [Neodiprion sertifer (Geoffroy)], cabbage looper [Trichoplusia ni (Hubner)], tobacco hornworm [Manduca sexta (Johannson)], codling moth [Carpocapsa pomonella (L.)], pink bollworm [Pectinophora gossypiella (Saunders)], tobacco budworm [Heliothis virescens (F.)], peach tree borer [Sanninoidea exitiosa (Say)], spotted cucumber beetle (Diabrotica undecimpunctala howardi Barber), and others. Procedures similar to those outlined for the boll weevil and codling moth could undoubtedly have a major impact on the reproductive potential of low-level populations of many species if suitable techniques were developed. Jacobson (1965) recently compiled the information available pertaining to insect sex attractants. He listed a wide range of insects that produce pheromones to attract one sex or the other. Research to identify, determine the chemical structures of, and eventually synthesize these attractants should be emphasized. Considerable effort is being devoted to such investigations by personnel of the Entomology Research Division and members of other research groups. It is obvious that a synthetic attractant equal in activity to the natural attractant, if available in large quantity, and at low cost per unit of attractant power, would offer advantages that the living insects, or their equivalent in extracts, would not have. Therefore, research to synthesize sex attractants of all key insect species should be given the highest priority.

474. . 1966. Some basic principles in insect population suppression. Bull. Entomol. Soc. Am. 12: 7-15.

The basic principles of insect population suppression and how these principles can be applied alone or properly integrated in the topic I wish to discuss with you on this occasion. I am confident that with new techniques of control and

with new concepts in their use we can develop methods of regulating many of the major insect populations to the extent that all damage can be prevented, in a way that will avoid or greatly minimize hazards to other forms of life in the environment, and at a continuing cost that will be much lower than the procedures we now follow. An all out approach to insect population control will not be practical or justified for all the destructive insects. But in advocating research on this approach, I have in mind some of our key insect species-those that are responsible for our greatest losses; those that now require expenditures in terms of millions for control year after year; and those that are now responsible for the most extensive use of insecticides. I have in mind such insects as the cotton boll weevil (Anthonomus grandis Boheman), screw-worm (Cochliomyia hominivorax (Coquerel), corn earworm (Heliothis zea (Boddie)), tobacco hornworm (Manduca sexta (Johannson)), tobacco budworm (Heliothis virescens (F.)), cabbage looper (Trichoplusia ni (Hubner)), codling moth (Carpocapsa pomonella L.), sugarcane borer (Diatraea saccharalis (F.)), Euporean corn borer (Ostrinia nubilalis (Hubner)), pink bollworm (Pectinophora gossypiella (Saunders)), tropical fruit flies (Tephretidae), cattle grubs (Hypoderma spp.), face fly Musca autumnalis De Geer), and perhaps other important agricultural pests that in the aggregate take a major toll or represent major threats to our agricultural resources. If we can eventually take care of some of these major pest problems by the total population control concept without adversely affecting the beneficial insect complex in the environment, we would at the same time make it possible for natural biological agents to do a better job controlling other important insect problems.

475. . 1968. The potential role of sterility for pest control. In Principles of Insect Chemosterilization, G. C. La Brecque & C. N. Smith (ed.), Appleton-Century Crafts. New York. pp. 7-40.

The sterility techniques for controlling insects and other pests are receiving the attention of an increasing number of research scientists. The techniques involved permit the application of certain principles of population suppression that could lead to more efficient or more desirable solutions to many important insect problems. Certain sterility procedures should prove equally useful for meeting many vertebrate pest problems. The extent to which the sterility techniques will be employed for regulating pest populations will be contingent on the degree of progress that is made in several fields of research. It will be necessary to develop safe chemical sterilants or other ways of achieving the appropriate type of sterility. Application of the techniques will require a good understanding of the biology, behavior, ecology, and population dynamics of the pests involved. If sterility involves the natural population, practical ways of achieving the necessary level of sterility must be perfected. If the sterility technique involves the release of reared insects, such insects must be mass produced at a reasonable cost. Up to the present time, two methods of producing sterility have been investigated most extensively. One methods involves the exposure of the organism to X-rays or gamma rays from Cobalt 60 isotopes (Bushland and Hopkins, 1951, 1953). The other involves the use of chemicals that produce sterility. These methods cause dominant lethal effects in the genetic material. Sterility can also be achieved by crossing species or races of insects. In this chapter we will not be concerned with the merits or limitations of various ways to induce sterility. We are concerned here with the fundamentals of population suppression by the use of the sterility techniques, irrespective of the methods used to produce sterility in the organism. A full understanding of the fundamental principles involved in the suppression

of pest populations by various other systems of control is also necessary, since different methods of control affect population trends in different ways. Such understanding of the merits and limitations of different methods will suggest ways to integrate the sterility method with other systems of control.

476. . 1968. Technically feasible approaches to boll weevil eradication. Proc. 1968 Beltwide Cotton Prod.-Mech. Conf., pp. 14-18.

Regardless of the method or combination of methods employed, eradication will not be achieved unless the suppression measures are applied against the total population of the insects. We cannot expect to develop a permanent solution by uncoordinated individual effort, regardless of the control methods employed. The boll weevil, like most insects, has a tremendous capacity to increase in numbers and it can disperse readily. In spite of the extensive use of highly effective boll weevil insecticides for 20 years, we continue to have as many or more boll weevils at the start each spring as we had twenty years ago. If we are to find and implement a permanent solution to the boll weevil problem, we must keep two objectives in mind: (1) We must develop highly effective, economical, and acceptable methods of control; (2) We must apply the control measures against the total population in an organized, coordinated, and efficient manner.

477. . 1971. Boll weevil and pink bollworm eradication: Progress and Plans. Proc. 1971 Beltwide Cotton Prod.-Mech. Conf. Cotton Ginners Jour. and Yearbook. March issue, p. 23-30.

Two insect suppression programs underway or planned by the U.S. Department of Agriculture, the cooperating State Departments of Agriculture, Experiment Stations, and the cotton growers are of vital importance to the cotton industry: the pink bollworm containment program under way in western cotton-growing States and the planned pilot test program in the Midsouth to determine if boll

weevil eradication is technically and operationally feasible. These programs should be of equal interest to environmental scientists and administrators and to the public who are concerned over the adverse impact of insecticides now employed to control these pests.

478. . 1972. Entomology and the management of man's environment. J. Aust. Entomol. Soc. 11: 153-167.

I have discussed the management of populations of the boll weevil and codling moth and the highly selective insect control methods that may be used in controlling insect pests. I acknowledge that entomologists and their many associated scientists face many problems, as they always have, in their continuing efforts to cope with man's chief competitor, the insects. Outstanding advances have been made in the past quarter-century even though we see many fundamental weaknesses in the tactics and strategies employed. But I am confident that they can meet the real challenge of the future; the development of methods for dealing effectively and economically with most major insect pests, in ways that are acceptable from the standpoint of maintaining the quality of the environments in which we live.

479. . 1976. Biomathematical basis for suppression and elimination of boll weevil populations. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 130-148.

The uncoordinated use of insecticides and other control measures as practiced during the past half-century will never resolve the boll weevil problem in a satisfactory manner. The pest will continue to cause high losses, and intensive use of insecticides will be required year after year, which in turn will result in a continuation of ecological disturbances that intensify bollworm, budworm, and

other pest problems. Two alternatives for a more acceptable solution to these problems should be given serious consideration by those responsible for dealing with them. (1) The institution of a well-organized and unified boll weevil management program designed to reduce populations each year to a level that will not require in-season applications of insecticides. This is necessary to make possible effective management of the bollworm, budworm, and other secondary pests by integrated systems that rely primarily on natural biological control. (2) The institution of a program designed to eliminate the boll weevil from all areas of the Cotton Belt and maintain elimination of incipient infestations that may result from infiltrations from Mexico or from wild hosts in South Texas. Based on an analysis of the dynamics of the boll weevil and current methods of suppression, intensive use of insecticides will be required in the fall each year to reduce overwintered populations to a level that will assure no need for in-season insecticide applications. However, based on simulated suppression methods, the prospects are excellent that such reduced population will be amenable to further suppression or elimination by employing the boll weevil pheromones and sterile males, two techniques that are completely selective in action on the target pest. The principles and mechanisms of suppression inherent in these new techniques when employed alone and when employed as components in integrated systems add new dimensions to boll weevil suppression strategies. The use of in-field pheromone traps as a method of suppression and as a highly sensitive method of detecting low-level populations shows unusual promise, based on theoretical suppression models.

480. . 1976. Boll weevil eradication experiment. (Abstract) In Public-Supported Cotton Research. Proceedings of Conference of Collaborators from Southern Agricultural Experiment Stations. U.S. Agric. Res. Serv. [Rep.] ARS-S-70, p. 12.

During the late 1960's pilot plant tests were undertaken to determine if an

isolated boll weevil population could be eliminated through use of several integrated suppression methods. The area selected for 2-year experiments consisted of over 20,000 acres of cotton centered in southern Mississippi and extending into Louisiana and Alabama. The central core of approximately 3,000 acres constituted the eradication test area. Buffer zones around the core, ranging in width from about 15 to 25 miles, constitute a general suppression area where insecticides were used to minimize migration of boll weevils into the central core area. The pilot experiments were designed to test the feasibility of boll weevil eradication and to further develop technology for large-scale operations. The program is a cooperative effort by many Federal, State, and cotton industry institutions, financed by the Agricultural Research Service, Animal and Plant Health Inspection Service, Cooperative State Research Service, and Cotton Incorporated. The boll weevil rearing facility was constructed by Mississippi State University. Several suppression systems were applied in the core and first buffer areas during the first year. Intensive applications of insecticides to limit reproduction and diapause were made to the core and first buffer zone in the fall, supplemented by defoliants and stalk destruction. The next spring pheromone-baited traps and trap crop plantings were employed to further reduce the boll weevil population. Supplemental insecticide applications were also employed at pinhead square time. The last suppression component consists of sterile male releases. Tests are now in the second year.

481. . 1976. Report of Technical Guidance Committee for the Pilot Boll Weevil Eradication Experiment. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 122-125.

Based on the results and experiences gained in the Pilot Boll Weevil Eradication Experiment conducted in south Mississippi and adjacent areas in Alabama and

Louisiana, and mindful that the experiment was conducted in an area representative of the most severe boll weevil conditions likely to be encountered in the boll weevil belt, the Technical Guidance Committee has reached the conclusion that it is technically and operationally feasible to eliminate the boll weevil as an economic pest in the United States by the use of techniques that are ecologically acceptable. The economic and environmental benefits of achieving this goal will far exceed the costs that will be involved. For such program to be successful, it must be carried out with thoroughness and precision. The participation of a number of agencies will be required. Complete cooperation and participation by all cotton growers in the boll weevil belt is essential.

482. . 1978. Eradication of Plant Pests - Pro. Advances in Technology for insect populations eradication and suppression. Bull. Entomol. Soc. Am. 24: 44-52.

Scientists have different views on the most practical approach to the protection of plants and animals from insect attack. This is understandable because of the diversity of insect problems; the wide range in biology, habits, and behavior of pests; and the many factors that determine the most effective and practical procedures to employ from the standpoint of costs and benefits and ecological impact on the environment. I propose that 3 control methods be recognized in our long-range efforts to provide practical and ecologically acceptable solutions to insect pest problems: (1) Eradication of pests from specified areas when it is demonstrated to be technically and operationally feasible and economically advantageous, (2) management of some major pests by an organized and coordinated attack on pest populations on an area-wide or ecosystem basis, and (3) the critical monitoring of pest conditions and the application of appropriate control measures where and when pests appear in damaging numbers. The 3rd method has been the procedure relied upon for most pests in the past. Such procedures based on better monitoring techniques and more judicious selection and use of

control measures has received special emphasis in recent years. The application of insecticides as a preventive measure in advance of the appearance of economical numbers of certain pests is still practiced by growers to some degree. Preventive measures may be the most logical solution for many pest problems, but this approach has led to justifiable criticism in some cases because of the ecological disruption caused by excessive or unnecessary applications of broad-spectrum chemical insecticides. If this objectionable feature can be avoided by the use of target-pest-specific methods, preventive entomology should be accorded the same recognition now received in preventive medicine. Among the 3 attempting approaches, the feasibility and justification for attempting eradication of well-established pests from specified areas is probably the most controversial among members of the entomological community. Some of the controversy is due to differences in interpretation of the meaning of eradication. Those who are in general opposition to the concept of eradication also cite examples of costly efforts that failed to achieve the objective. There is also wide divergence of viewpoints on the capability of achieving eradication of pests with available technology.

483. , and McQuire, J. U., Jr. 1966. Population models to test the theoretical effects of sex attractants used for insect control. U.S. Dep. Agric. Inf. Bull. 308, 20 pp.

Use of models to test effects of sex attractants are described for the codling moth [Carpocapsa pomonella (L.)] and the boll weevil (Anthonomus grandis Boheman) with implications for use for other insects which respond to sex attractants.

484. Kormarck, E. V., Sr. 1970. Insect control: fire for habitat management. In Proc. of Tall Timbers Conf. Ecol. Anim. Habitat Manage. 1969. 1: 157-171, Tall Timbers Res. Sta. Tallahassee, Fla.

Fire as a natural environmental regulator of animal populations particularly insects, has certainly been long overlooked. The selected and incomplete literature review indicates not only a basis for insect control but also the need for studies in the fire ecology of insects in this region. The effect of fire in its intricate relationships with insects, if known, might well become important as an ecological control of insects by habitat management.

485. Kuehl, R. O., and Fye, R. E. 1972. An analysis of the sampling distributions of cotton insects in Arizona. J. Econ. Entomol. 65: 855-860.

Enumeration samples of various insects associated with cotton were collected over a 3-year period in commercial cotton fields to evaluate their statistical properties. Samples from relatively low-density populations agreed with Poisson expectations while samples indicating relatively dense insect populations agreed with expectations of the negative binomial distribution. The number of plants per sample unit influenced the statistical distribution of the samples. Cotton-insect populations tend to be clustered, but the clustering is detected only under very intensive samppling or when population density is high. Several biological models can lead to the same statistical properties of the sampling distributions.

486. Kulkarni, P. G.; Mitlin, N.; and Hurst, G. A. 1973. Toxicity of busulfan and influence of ingested chemosterilized boll weevils on reproductive performance of the Japanese quail. J. Econ. Entomol. 66: 341-343.

Busulfan-sterilized males of Anthonomus grandis Boheman were released in cotton fields of south Mississippi, Alabama, and Louisiana as part of the boll weevil eradication experiment. Laboratory experiments were conducted on the Japanese

quail, Coturnix coturnix japonica (Temminek & Schlegel), to assess the effects of the toxicity of busulfan ingested, chemosterilized weevils on certain species of wildlife. The acute toxicity of busulfan to quail chicks at age 1 week was 162.7 mg/kg. Toxicity for males and females at age 8 weeks was 160.3 and 174.3 mg/kg, respectively. Gland weights of testes and ovaries were affected at LD_{50} or at a higher dose. Quail chicks were fed chemosterilized weevils. Eggs of these quail and their offspring were analyzed for egg production, fertility, hatchability, shell thickness, abdomen, and yolk contents. Chemosterilized weevils had no significant effect on the reproductive performance of Coturnix quail.

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487. Lacewell, R. D.; Bottrell, D. G.; Billingsley, R. V.; Rummel, D. R.; and Larson, J. L. 1974. Impact of the Texas High Plains diapause boll weevil control program. Tex. Agric. Exp. Stn. Misc. Publ. MP-1165, 16 pp.

Cotton producers on the Texas High Plains in cooperation with the U.S. Department of Agriculture have been carrying out an area-wide boll weevil suppression program. The purpose of the program has been to prevent the boll weevil from becoming established on the Texas High Plains. With the program in effect, an estimated 2.2 million pounds of insecticide are applied annually to cotton on the High Plains and the Rolling Plains. Based on 1969, 1970 and 1971 statistics, about 1.7 million bales were produced annually. With the suppression program discontinued, it was estimated that insecticide use would increase between 8 and 20 million pounds annually, cotton output would decline between 75,000 and 125,000 bales and total production costs would increase between $12 and $20 million over the total area (High Plains and Rolling Plains). The estimated increase in insecticides applied was primarily because producers would use toxaphene and methyl parathion to control boll weevils that establish

near and on the High Plains if the suppression program is withdrawn. The results suggest that the suppression program not only is effective in protecting the High Plains from boll weevil infestation but also contributes significantly to an increased cotton output, a reduced cost of production for producers and a reduced quantity of insecticides introduced into the environment.

488. ; Larson, J. L.; Bottrell, D. G.; Rummel, D. R.; and Billingsly, R. V. 1974. Economic implications of discontinuing the Texas High Plains boll weevil suppression program. South. J. Agric. Econ. 6 (Dec.): 33-40.

The federal government has supported and continues to support or share in the support, financially and technically, of several regional pest management programs. Implicit in continued federal support is the concept that the benefits of the program to society exceed the governmental portion of the cost. As these programs are evaluated and consideration is given to discontinuing federal support, improved estimates of program benefits, or costs of discontinuing, are needed. The objective of this study was to identify and quantify the expected effects in terms of agricultural output, insecticide use, and production costs of discontinuing a regional boll weevil suppression program on the Texas High Plains. Results of this study are useful to governmental decision makers, local producers, environmentalists and economists.

489. ; Sprott, J. M.; Niles, G. A.; Walker, J. K.; and Gannaway, J. R. 1976. Cotton grown with an integrated production system. Trans. ASAE 19: 813-818.

The economic, environmental, entomological, agronomic and energy use characteristics of narrow-row, short-season cotton grown under an integrated production system were evaluated. This cotton production system reduced energy use per hectare from 8,956,205 kcal to 6,042,651 kcal, or a savings of 33 percent. More dramatically, energy required per kg of lint declined from 15,981 to 7,049

kcal, saving 56 percent. This producton technique also required 27 percent fewer kilograms of active ingredients from insecticides and herbicides. Economic evaluation indicated a potential savings in costs per kg of lint of 43 percent, from $1.04 per kg production cost under the typical Frio County production technique to $0.593 per kg using the narrow-row, short-season pest management technique. Overall, it appears that this new production system is in harmony with environmental and energy use goals, while also being very attractive to the individual producer. Producer acceptance of the new integrated production system is most encouraging as it is used on an increasingly larger number of acres each year.

490. , and Taylor, R. C. 1978. Economic implications of alternative boll weevil control strategies. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228: 104-125.

Beltwide boll-weevil-control alternatives are being developed and proposed to benefit farmers. This analysis strongly suggests that, in the aggregate, farmers in their role as landowners are not beneficiaries of the programs. Rather, landowners lose because land values fall. It is consumers and other products that benefit, through lower prices. This general pattern has been found for many new technologies that have been adopted by farmers. A net positive social benefit provides reasonable justification for pursuing a program. However, it leaves unanswered the question of equity between those who incur a cost and those who benefit (at the producer and consumer levels). These ramifications and the identification of actual beneficiaries and losers have too long been ignored in large state and federal programs. This study examined expected effects of three alternative boll-weevil-control programs. The results suggest that eradication may not be the optimum boll-weevil-control alternative for either society or the producer. The analysis indicates that an alternative that would require some additional research but potentially

could put into practice in five to ten years has the largest potential. However, the likely costs to acquire these benefits need to be considered carefully. A boll-weevil-control alternative that presently exists and could be put into practice within one year would provide social benefits $331 million larger than an eradication program. Considering the uncertainty associated with per-acre yield and cost effects of alternative boll-weevil-control strategies, there is justification for developing an improved data set. Through careful management and data collection in the optimum pest-management trial in Mississippi and the eradication trial in North Carolina, more refined estimates of cost and yield effects may become available and the evaluation may be updated. This analysis suggests that, in the interim, there are opportunities for developing vastly improved boll-weevil-control strategies with available technology. Substantial social benefits would evolve that justify a strong continued effort to develop improved cotton production systems in which boll weevil control is but one aspect.

491. Lambert, L.; Jenkins, J. N.; Parrott, W. L.; and McCarty, J. C. 1980. Evaluation of foreign and domestic cotton cultivars and strains for boll weevil resistance. Crop Sci. 20: 804-806.

Forty-four domestic and introduced cotton (Gossypium hirsutum L.) cultivars and strains were evaluated in the laboratory for resistance to the boll weevil, Anthonomus grandis Bohe. Oviposition by the boll weevil was significantly lower in squares (flower buds) from eight cottons ('Lasani 11, ' 'AC 134,' 'Albar 627,' GO77-2, 'BP 52/NC 63,' TX-LY-18-72, DES-HERB 16, and DES-ARS 16) than in squares from the commercial cultivar, 'Deltapine 16'. Five of the eight were introductions. Oviposition was not significantly lower in any entry than in 'Stoneville 213', another commercial cultivar. There was no significant correlation between terpenoid aldehyde content in squares of 10 entries and rate of oviposition. The potential of the entries in breeding for increased resistance to the boll weevil is discussed.

492. ; Lentz, G. L.; and Cherry, E. T. 1977. Development period of the boll weevil at different temperatures during the growing season in west Tennessee. Environ. Entomol. 6: 350-352.

The development of boll weevils from egg to adult emergence was studied in relation to temperature at Jackson, TN, during 1974. The development period varied with average temperature. Average temperatures ranged 20.67°-27.12°C. Development periods ranged 16.28 days. Variability increased as average temperatures ranged 16-23 days. Variability increased as average temperatures decreased. Development periods can be estimated using a linear regression equation.

493. ; Lentz, G. L.; Cherry, E. T. 1979. Preoviposition periods and oviposition rates of insectary-reared boll weevils in west Tennessee. Environ. Entomol. 8: 1092-1094.

Preoviposition periods and oviposition rates were determined for Anthonomus grandis grandis Boheman emerging each week throughout the 1974 cotton growing season. Preoviposition periods increased as the season progressed, ranging from a mean of 1.96 days in late July to 6.19 days in late Aug. Deviation from the mean also increased as the season progressed, ranging from ±0.57 days for one standard deviation, in late July to ±2.59 days in late Aug. The average number of eggs deposited per female per day for the 1st 14 days after emergence was 4.47 in late July. For weevils emerging in early September, the 14-day average had decreased to 0.52 eggs/female per day.

494. Lambremont, E. N., and Bennett, A. F. 1966. Lipid biosynthesis in the boll weevil. Formation of the acetate precursor for lipid synthesis from glucose and related carbohydrates. Can. J. Biochem. 44: 1597-1606.

Glucose, sucrose, fructose, and their related glycolytic products, pyruvate and acetate, were readily converted into long-chain fatty acids by larval and adult boll weevils (Anthonomus grandis Boheman, Coleoptera:Curculionidae).

By comparison of the radiorespirometric formation of $^{14}CO_2$ of adults injected with differentially labeled glucose and pyruvate to the specific activity of lipid synthesized from these substrates, it was determined that glycolysis is the principal pathway by which acetate is produced. The patterns suggested that the boll weevil possesses the pentose phosphate pathway, which also accounts for a significant oxidation of glucose. Recombinations of labeled carbon atoms within and between intermediates of the pentose cycle allow synthesis of labeled fatty acid to take place with those carbons of glucose which could not ordinarily enter fat synthesis by glycolysis alone.

495. ; Bennett, A. F.; and Stanley, R. F. 1967. Modified laboratory techniques for preparing sterile larval diets for the boll weevil. J. Econ. Entomol. 60: 1473.

By autoclaving the whole diet minus the B-vitamins, we have returned to successful rearing of boll weevils in both vials and petri dishes. Also this diet, which is completely sterile, can be used to study lipid synthesis in the boll weevil because C^{14}-labeled metabolites can be added directly. (Obviously any possible effects of microbial contaminants in such type of work must be excluded). Although we have autoclaves C^{14} fatty-acid diets with no detectable loss of radioactivity, we recommend filtering them through a Millipore filter into the cooled diet. Aliphatic and aromatic hydrocarbon solutions of such labeled metabolites will not damage the filter.

496. ; Bumgarner, J. E.; and Bennett, A. F. 1966. Lipid biosynthesis in the boll weevil (Anthonomus grandis Boheman) (Coleoptera: Curculionidae): distribution of radioactivity in the principal lipid classes synthesized from C^{14}-1-acetate. Comp. Biochem. Physiol. 19: 417-429.

1. The boll weevil, Anthonomus grandis Boheman, synthesized fatty acids and hydrocarbons from acetate. The fatty acids were rapidly esterified with glycerol

and sterol or were incorporated into the phospholipid fraction. Radioactivity was not incorporated into the sterol fraction, an indication of the absence of sterol biosynthesis from acetate. 2. The feeding history and developmental state of the adult boll weevil determined the eventual location of the newly synthesized fatty acids. Newly emerged unfed adults incorporated the fatty acids principally into the phospholipids. In insects injected with radiolabeled acetate after several days of feeding, the new fatty acids were distributed to the glycerides. 3. Larvae fed a diet containing labeled acetate had an entirely different labeling pattern with much higher amounts of C^{14} appearing in the free fatty acid fraction.

497. , and Wood, R. 1968. Glyceryl ethers in insects: identification of alkyl and alk-1-enyl glyceryl ether phospholipids. Lipids 3: 503-510.

Alkyl and alk-1-enyl ethers have been identified in the phospholipids of three insect species, the American cockroach (Periplaneta americana), the tobacco budworm (Heliothis virescens), and the boll weevil (Anthonomus grandis). Glyceryl ethers were not detected in the neutral lipids. The ethers were found in the phospholipid fraction of whole insects and in isolated fat body tissue. The ether content varied among the three insect species, and fluctuated during various developmental stages. Gas liquid chromatographic analysis of the alkyl glyceryl ethers and aldehydes derived from the alk-1-enyl glyceryl ethers of the cockroach and budworm showed striking differences in chain length. However, the hydrocarbon side-chain of the two ether fractions were similar in length for each species. Preliminary evidence indicates that 1-^{14}C-acetate can be incorporated into alkyl ethers but not into alk-1-enyl ethers of Heliothis pupae.

498. Leggett, J. E. 1979. Boll weevil: some new concepts in trap design and evaluation of trap efficiency. Environ. Entomol. 8: 70-72.

Traps that captured boll weevils, Anthonomus grandis grandis Boheman, alive were more effective than traps requiring an adhesive. A thixotropic adhesive was convenient to work with but did not weather satisfactorily. A trap that turns with a slight breeze did not capture more weevils than stationary traps. A latin square in time experimental design was effective in removing variation of mean weevil capture due to effects of season and trap location when trap designs were compared around a cotton field. A commercial trap based on the design of the Leggett trap was effective in capturing weevils. Pigmented adhesive sprayed on a cotton plant was ineffective in capturing boll weevils that responded to grandlure.

499. . 1980. Boll weevil: competitive and non-competitive evaluation of factors affecting pheromone trap efficiency. Environ. Entomol. 9: 416-419.

The effect of trap heights above soil surface was determined when traps of different heights were competing to attract released boll weevils, Anthonomus grandis Boheman, and where the heights were separate and not competing for capture of the same weevils. Other factors compared in the same way were trap color, trap design, grandlure concentration, and ratio of the 4 grandlure components. These tests were conducted to determine the degree of bias that may result when trap factors compete for a natural field population of boll weevils. The importance of trap height, color, design and grandlure concentration was less in noncompetitive tests; however, 30:40:30 and 50:33:17 ratios of grandlure compounds I:II:III&IV were equally effective in both comparisons.

500. ; Cleveland, T. C.; and Scott, W. P. 1972. Comparison of several insecticide combinations for control of Heliothis spp. J. Econ. Entomol. 65: 1182-1183.

The following insecticides applied by ground machine were equally effective in controlling boll weevil and bollworms on cotton in N. E. La. during 1967, 68, and 69: Methyl parathion at 0.75 lb AI/a, methyl parathion (0.75) and DDT (1.0), toxaphene (2.0) + methyl parathion (0.75), toxaphene (2.0) + DDT (1.0), toxaphene (2.0) + DDT (1.0) + methyl parathion (0.75).

501. , and Cross, W. H. 1971. A new trap for capturing boll weevils. Coop. Econ. Insect Rep. 21: 773-774.

The trap is constructed from a floral liner (papier-mache material) 11.5 in. high. The inverted floral liner is painted first with a white undercoat, then with daylight fluorescent Saturn Yellow (Day-Glo® 2/ Color Corporation), and finally with a clear acrylic lacquer for waterproofing and to prevent fading of the Saturn Yellow. The floral liner is capped with a screen cone held just off the liner with glass beads or other spacers with a small hole in the apex of the cone which opens into a 2-in.^{3} plastic box (or similar device) (Fig. 2). A grandlure wick is pinned to the top of the floral liner inside the screened cone. The complete trap is mounted on a stake 3 to 4 ft. above the ground. Weevils may be captured and kept alive or they may be killed with a small cube of Vapona® No-Pest strip placed in the box.

502. , and Cross. W. H. 1976. Response of boll weevils and other insects to grandlure exposed in two basic types of traps. J. Econ. Entomol. 69: 6-8.

When compared to the Whittam trap, the Leggett trap was highly selective for capturing Anthonomus grandis Boheman and accounted for 58% of the total insects captured when baited with grandlure. No other insects responded to grandlure. Traps painted Saturn Yellow were attractive to several other groups of insects.

503. , and Cross, W. H. 1978. Boll weevils: the relative importance of color and pheromone in orientation and attraction to traps. Environ. Entomol. 7: 4-6.

Saturn Yellow was important in orienting and attracting boll weevils, Anthonomus grandis Boheman, to baited and unbaited traps at a distance of 2 m or less; moderately important at distances up to 6 or 7 m; and not important at greater distances. When boll weevils were given a choice between 2 colors of traps in the same circle, the average number of responding marked females was the same (28%) regardless of whether the red traps were baited and the yellow traps unbaited or whether grandlure was in all traps. However, untreated (no pheromone) Saturn Yellow traps spaced 8 m apart caught only 4.4% of released female boll weevils.

504. ; Cross, W. H.; Mitchell, H. C.; Johnson, W. L.; and McGovern, W. L. 1975. Improved traps for capturing boll weevils. J. Ga. Entomol. Soc. 10: 52-61.

When trap designs were tested to determine the most efficient type to use with grandlure in capturing Anthonomus grandis Boheman, the conical, non-sticky Leggett trap was more efficient than a similar trap coated with adhesive. The size of the trap (17 or 29.5 cm high) was a minor factor in number of weevils captured. The location of grandlure on the Leggett traps was not a factor in the capture. Glass beads on the surface of live traps made them less attractive. Bicolored traps were less effective than traps painted all Saturn Yellow (Day-Glo®). However, daylight fluorescent pigments mixed with tack trap placed on paper wing traps were as effective as those traps painted with Saturn Yellow and then coated with tack trap. Caution Yellow and Lightning Yellow (at least in early season) were as attractive as Saturn Yellow to boll weevils.

505. , and Fye, R. E. 1969. The role of moisture in the winter survival of the boll weevil complex in Arizona. J. Econ. Entomol. 62: 147-149.

Studies made with temperature-control cabinets set for the average day and night soil temperatures at Stanfield, Arizona, and with several levels of moisture showed that winter survival of the boll weevil, Anthonomus grandis Boheman, complex was affected by moisture. Longevity after emergence increased when the levels of moisture in the bolls and in the simulated trash in which the weevils were hibernating were above 0.5 and 0.044 g of water/g of boll and trash, respectively. Some weevils freed from the bolls early in the winter survived long enough to oviposit in the 1st squares produced by cotton plants in the subsequent season and could serve as precursors for later damaging generations.

506. , and Taft, H. M. 1979. Boll weevil: capture in pheromone traps baited with natural male lure and several concentrations of grandlure. Environ. Entomol. 8: 62-64.

Traps baited with slow release formulations of grandlure (30-40 mg/trap) remained effective for 6 wk without rebaiting and captured more boll weevils, Anthonomus grandis grandis Boheman, than traps rebaited weekly with 3 or 6 mg of grandlure. A 2-fold increase in grandlure concentration produced a significant increase in weevil capture, but captures were not increased additionally by a 4-fold increase when the 2 concentrations were not competing for capture of the same weevils. There was little difference in the attraction of boll weevils to one wick containing 3 mg of grandlure or to one laboratory reared male boll weevil that had fed on cotton squares.

507. Lincoln, C. 1969. The effect of agricultural practices on insect habitats in a typical Delta community. Proc. Tall Timbers Conf. Ecol. Animal Control Habitat Manage. 1: 13-18.

The Jefferson community in Desha County, Arkansas has undergone two revolutionary habitat changes in the past 20 years. The synthetic organic insecticides made possible great increases in cotton yields. By destruction of beneficial as well as pest insects they required additional insecticide inputs. An appreciation and knowledge of these beneficial insects led to an effective program of integrated control.

508. . 1976. Seasonal development of the boll weevil. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, p. 9.

A given field may provide abundant squares for weevil development for 6 to 9 weeks, depending on soil fertility, variety, weather, irrigation, etc. At 2.5-fold rate of weekly increase, the seasonal population increase would be 100-fold in 6 weeks and 1,600-fold in 9 weeks. A boll weevil control program, as presently practiced, utilizes the actual rate of increase in deciding whether or not to apply insecticides. In a boll weevil elimination program, it would be prudent to assume the maximum rate of increase.

509. . 1978. Discussion and evaluation of alternative approaches to boll weevil management. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 126-130.

Immediately available management strategies practiced to varying degrees are: 1) off-season suppression or avoidance of heavy carry-over populations by use of insecticides for diapause control, destruction of favorable hibernation sites where they are limited in area, growing of cotton in low-hazard

areas, and early harvest and stalk destruction where a long growing season permits; and 2) in-season suppression or control utilizing uniform planting dates, fast-fruiting determinate varieties, regular and careful scouting with application of insecticides as-needed on a very conservative basis with prompt termination once the material has served its purpose, and capitalizing on hot, dry weather as a natrual control. Future management strategies would include resistant varieties; development and belt-wide use of adapted, high-yielding, fast-fruiting, determinate varieties; biological control; more effective use of the pheromone grandlure, and discovery and development of effective insecticides from different chemical groups. Hopefully, such new insecticides would be selective for boll weevil and have minimum impact on biological control agents of boll weevil and other pests, if such become established in effective numbers. Many of these strategies would be more effective if applied to a large area rather than to individual fields. The cotton plant can tolerate heavy square loss from boll weevil. More detailed, quantitative information on square loss is needed in relation to performance of the cotton plant under specific conditions. Agronomic practices such as over-fertilization, over-irrigation, or misuse of herbicides can negate the benefits from fast-fruiting cottons. Improved harvest-aid chemicals and proper timing of their use would help reduce diapausing weevil populations. Management of the cotton crop is of prime importance in management of boll weevil. Development of computer models, both long-range and short-range, offers great promise in managing both the cotton crop and the boll weevil. A team approach among all disciplines concerned with cotton production and marketing is needed if rapid progress is to be made on boll weevil management and its implementation.

510. . 1978. Integrated insect management systems: integrated insect control in the Mid-South - Dwight Isely to present. In Proc. of Symp. on Development of Optimum Crop Production Systems for the Mid-South. Univ. of Arkansas Special Report 67: 101-103, Fayetteville, Arkansas.

Dwight Isely developed a boll weevil pest management system utilizing scouting and spot dusting in the 1920's. He placed students with farmers to scout their cotton, with farmers paying for the service. Lack of an adequate information delivery system prevented widespread adoption of this pest management system. In other research on cotton pests Mr. Isely reared boll weevils and bollworms under controlled conditions of temperature, relative humidity, and food; studied varietal escape and resistance, demonstrated the value of winter clean-up of weevil hibernation quarters in bottomland areas, showed spot dusting to be a practical remedy for spider mite infestations, related cotton aphid development and fecundity to plant nutrition, and did a lot of trouble-shooting in the absence of an Extension Entomologist. He researched the new synthetic insecticides but insisted that scouting and timing of insecticide applications were the keys to good control, rather than making automatic or scheduled treatments. An Extension Entomologist was hired in Arkansas in 1942 and widespread education of County Agents and farmers in the principles so long advocated by Mr. Isely became a reality. Scouts paid by farmers developed into a major program. Research on IPM has continued under Mr. Isely's successors. These studies include host plant resistance, thresholds, native predators, insect pathogens, pink bollworm source and potential in Arkansas, clarification of the *Heliothis* complex, life and seasonal history studies with emphasis on diapause, the plant bug complex, status of *Heliothis* as an induced or primary pest, elucidation of chlordimeform as a pest management tool, areas of greater or lesser *Heliothis* hazard, improvement and evaluation of scouting methods, and development of a community-wide rather than a field by field approach to cotton

insect control.

511. . 1978. Procedures for scouting and monitoring for cotton insects. Arkansas Agric. Exp. Stn. Bull. 829, 36 pp.

Several cotton fields were scouted weekly for cotton insect infestations and relevant crop performance information in 1974 and 1975, using conventional and innovative methods. Each field was scouted independently but simultaneously by two scouts. About half of the fields also were scouted by two more scouts at another time the same week. Counts included: 1) thrips by beating small plants against a "beater box", 2) node to 1st square, 3) sets of small squares, 4) plant bugs in terminals and squares, 5) predators in terminals, 6) bollworm-budworm eggs and small larvae in terminals, 7) plant bugs on drop sheet, 8) predators on drop sheet, 9) boll weevil-punctured squares, 10) bollworm-budworm-damaged squares, 11) squaring rates, 12) square size, 13) insect-mite infestations of leaves, 14) damaged white blooms, 15) plant densities, and 16) plant height. Use of a back-pack suction machine (D-Vac®) was compared to terminal and drop-sheet sampling. It proved to be about equally effective as the drop sheet in sampling for plant bugs and predators, and was the only effective method for leafhoppers. The drop sheet technique was much more productive than examining terminals for plant bugs and predators. However, statistical precision was not improved. Time required for each stop and total time per field was recorded in selected fields. In others, time required for each operation was recorded.

512. . 1980. Role of entomology in reducing cost of cotton production in 1980. Proc. 1980 Beltwide Cotton Prod. Res. Conf., pp. 313-314.

The greatest opportunity for impact of Entomology on cotton production in 1980 lies in two areas: 1) Scouting, surveillance, and decision-making. This requires lots of high-quality troops in the field. The growth of professionalism among Pest Management Consultants is most gratifying, but much remains to be done before

all people and technique problems are solved beltwide. 2) The best possible insecticide application, be it by air or ground. Mississippi is doing yeoman extension work with aerial applicators. Such work should be done beltwide and would have an immediate impact. In both of these areas the producer pays for the service. As long as he is satisfied with a sloppy job, this is what he can expect to get. Research on cotton insects is active and productive. Producers rapidly adopt improved practices as soon as they are proven.

513. , and Blair, B. D. 1977. Extension entomology: a critique. Annu. Rev. Entomol. 22: 139-155.

The paper gives origins, history, and current status of extension entomology in relation to agriculture, homemaking, and many recent demands and problems. The future of extension entomology is explored and its role as one phase of the entomological profession is evaluated.

514. ; Boyer, W. P.; Dowell, G. C.; Barnes, G.; and Dean, G. 1970. Six years experience with point-sample cotton insect scouting. Arkansas Agric. Exp. Stn. Bull. 754, 40 pp.

The Point Sample Method of scouting has been used in Arkansas by cotton insect scouts since 1962. This bulletin evaluates experiences with this method from 1962 through 1967. A total of 21 locations were included to represent the cotton-growing areas of Arkansas. Squaring rates by week of squaring were more variable than had been anticipated from the original research on which the Point Sample Method was based. Thus, scouting should begin when most plants have one countable square (diameter of 1/4 inch or greater without the bracts). The range appears to be 11,000 to 60,000 squares per acre during the first week of squaring. After that recommendations should be based on week of squaring and whether the number of squares per acre is rising, remaining at the same level, or dropping. In a typical field squaring will accelerate

for 5 weeks, remain at a plateau for 3 weeks, and then drop.

515. ; Boyer, W. P.; and Miner, F. D. 1975. The evolution of insect pest management in cotton and soybeans: past experience, present status, and future outlook in Arkansas. Environ. Entomol. 4: 1-7.

Soybeans and cotton occupy vast acreages of the alluvial soils of eastern Arkansas. In this greatly simplified agro-ecosystem, soybeans are usually grown without sustaining economic damage from insects. Serious outbreaks do occur, however, and on the average 15% of the acreage is treated annually. Much of the cotton in northeastern Arkansas is not treated. Outbreaks of bollworm and boll weevil regularly require insecticide usage in central and southern Arkansas. Insect pest surveys and individual field scouting are used as the basis for determining the need for insecticides on both crops. This insect pest management system has been 50 years in the making in Arkansas. Current research in various areas, including innovative practices, should lead to improvement in the system. In-depth studies of all aspects of the several agro-ecosystems are essential for long-term progress in insect pest management. Given professional dedication by entomologists, with support from the agricultural community, industry, federal and state governments, and the public, progress should accelerate rapidly.

516. ; Dean, G.; Waddle, B. A.; Yearian, W. C.; Phillips, J. R.; and Roberts, L. 1971. Resistance of frego-type cotton to boll weevil and bollworm. J. Econ. Entomol. 64: 1326-1327.

Frego-type cotton refers to a mutant form with rolled bracts in contrast to the flat and more-or-less enclosing bracts of normal plants. Research at the Arkansas Agricultural Experiment Station on the rolled bract mutation as a source of insect resistance has been carried on since 1958. Hunter et al. (1965) reported it to be the most promising source of resistance to boll weevil,

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Anthonomus grandis Boheman, found in an extensive search through a broad spectrum of Gossypium hirsutum germplasm. The original Frego mutant had several undesirable agronomic features. In 1964 cotton-insect scouts found several individual plants with rolled bracts in commercial cotton fields. Seed of several of these plants were saved. After a winter increase in Mexico, Frego-type cotton was planted in Arkansas in 1965. Lincoln and Waddle reported resistance to both boll weevil and bollworm, Heliothis zea (Boddie), from this planting. Releases of 2nd-stage bollworms and adult boll weevils into the cotton were used to obtain data on which these conclusions were based. Additional research was conducted on the rolled-bract mutation as a source of resistance to boll weevil and bollworm. The strain used was based on the 1964 collections with little subsequent selection. 'DPL Smoothleaf' appears to be the parent variety of this strain.

517. , and Graves, J. B. 1978. Insecticides: resistance and new insecticides formulation and application technology. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 74-83.

Boll weevil populations are not reduced sufficiently by climatic conditions and biological control agents to prevent infestations from exceeding established economic thresholds annually. Application of insecticides has been the principal means of controlling this key pest of cotton since calcium arsenate was first reported to be effective in 1918. However, widespread use of the arsenicals induced outbreaks of aphids, bollworms, and presumably tobacco budworm because of interference with biological control agents that ordinarily controlled these insects. The synthetic insecticide revolution of the 1940's produced the first really effective insecticides for all cotton pests. The increase in yield obtained from insect control with the new organochlorine insecticides such as DDT, BHC, toxaphene, and endrin was about double that obtained with the inorganic insecticides. The striking effective-

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ness of these chemicals caused many farmers to use them on a preventative basis rather than using them as needed when economic thresholds were exceeded. Resistance in the boll weevil to the organochlorine insecticides, first reported in 1955, developed through the boll weevil-infested part of the Cotton Belt within a few years. Organophosphorus insecticides such as methyl parathion, malathion, and azinphosmethyl were found to be effective and have been used almost exclusively for boll weevil control for two decades without any sign of resistance developing. New chemicals that offer promise in managing boll weevil populations are the synthetic pyrethroids and Dimilin®. Prior to the 1950's, most insecticides were applied as dusts. With the advent of the synthetic organic insecticides, liquid formulations, primarily emulsifiable concentrates, came into general use. Presently most applications are made with either high-clearance ground machines or airplanes in volumes of 1 to 5 gallons per acre. ULV (ultra low volume) application (1/2 gallon per acre or less) of insecticide has been demonstrated to be effective against the major cotton insect pests, especially when airplanes are used to make the applications. The advent of systemic insecticides greatly enhanced control of pests with piercing-sucking mouth parts such as thrips, aphids, spider mites, and plant bugs. However, aldicarb is the only systemic insecticide registered for boll weevil control and its use is rather specialized.

518. , and Parencia, C. R., Jr. 1977. Insect pest management in perspective. Bull. Entomol. Soc. Am. 23: 9-14.

Applied entomologists have been and are continuing to explore all control avenues of potential promise. The slowness of progress is a measure of the difficulty of the problems. Team efforts are underway among specialists in various phases of entomology and other disciplines to develop integrated approaches that utilize several means of pest population management rather than a single control measure. None of this is really new. That is what research in applied entomology has been

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about from the beginning of the 20th century. The easy problems have been largely solved and the difficult ones are being worked on. Perfection will never be reached nor is there any reasonable hope that control of most pest insects can be achieved without a considerable use of insecticides. We would be derelict in our duties not to continue to develop new insecticides and acaricides and to recommend the use of effective pesticides which present very limited hazard to the environment and to man.

519. , and Phillips, J. R. 1970. The impact of resistance to insecticides on cotton insect problems in Arkansas. Arkansas Acad. Sci. Proc. XXIV: 66-67.

In 25 years of heavy insecticide usage on cotton in Arkansas, resistance has become a problem with several pest insects and mites to the 3 principal groups of insecticides and miticides: the chlornated hydrocarbons, the organophosphorus compounds, and the carbamates. Development of control measures, chemical or otherwise, is not proceeding at a sufficiently rapid pace to stay ahead of the problem posed by insect resistance to insecticides.

520. , and Waddle, B. A. 1966. Insect resistance of frego-type cotton. Arkansas Farm Res. XV(Jan./Feb.):1.

Significant reductions in surviving worms and in damaged squares were associated with the Frego plantings. Length of recovered worms was essentially the same for both cottons, indicating that the Frego plants were nutritionally adequate. Bollworms did not shift their site of greatest activity to areas away from bracts on the Frego plants. In fact, most of the worms recovered in both varieties were associated with the fruits (squares, bolls, and blooms). Resistance to boll weevil was verified in the Frego planting. Two weevil releases were made in the Frego and check plantings. Each consisted of 50 male and 50 female weevils, which were dispersed at random over 10 rows 100 feet long. The low infestations

following the July 16 release were considered as evidence that the weevils left the release area in both varieties. The second release, at a site removed from the first, was more effective. The check variety exhibited 44 percent punctured squares as compared to 12 percent for the Frego plants, according to counts made two weeks after release. The rolled bracts of the Frego plants should permit better insecticide coverage of the exposed buds than on normal buds. Logically, one should expect a lower recovery of worms in Frego following a standard insecticide application. Such was not the case in these tests. No variety-insecticide interaction was detected.

521. Lindig, O. H. 1976. Mass rearing of boll weevils. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 50-52.

In less than two decades, the rearing of boll weevils has evolved from the laboratory rearing of a few insects per week on natural food to the production of millions per week. These advances are the result of the work of many researchers, the most important being the development of an artificial diet in 1957 by Vanderzant and Davich. The development of an artificial diet on which the boll weevil could be perpetuated not only started researchers to work on mass rearing, but also allowed nutritional studies to begin. Vanderzant subsequently made many studies on lipid requirements, and on defined diets to establish amino acid, carbohydrate, and mineral, and vitamin requirements. Gast (1963) realized that in order to mass rear the boll weevil, not only was an efficient and economical diet necessary, but mechanical devices were also required. Much of his work was on improving the procedures for egg extraction, implanting eggs on larval diet, and preparation of oviposition diets. He also designed improved cages for holding the adults and developed a method for collecting emerging adults. Many of his developments, some with modifications,

are still in use today, and all are adequate for production levels of 100,000 adults per week or less. Major changes in procedures and priorities were indicated, however, when the demands for boll weevils became millions per week. For an example, when only 10 to 20 gal of diet a day are required, autoclaving is an effective and efficient method of diet sterilization, but when daily requirements are several hundred or several thousand gallons, autoclaving is impractical, if not impossible. The same holds true in the forming and wax-coating of the oviposition diet. The implementation of flash sterilizers and pellet-forming machines solved most of these problems. Today, the quantity of diet sterilized and oviposition pellets produced is limited only by the size and number of machines one wants to operate.

522. _____. 1979. A replacement for cottonseed meal and meats in boll weevil diets. J. Econ. Entomol. 72: 291-292.

The cottonseed meal and cottonseed meats in the adults and larval diets of Anthonomus grandis grandis Boheman can be replaced successfully with Pharmamedia®. Percent egg hatch was significantly higher when females were fed Pharamedia diet. The use of this commercially available material saved time, equipment, labor, and electrical energy in preparing diets.

523. _____, and Malone, O. L. 1973. Oviposition of boll weevils fed diets containing germinated cottonseed puree or cottonseed meats puree. J. Econ. Entomol. 66: 566-567.

Use of the cottonseed meats puree reduced cost of the diet by 11¢/liter, 34.4%. The 16.1% fewer weevils and therefore the 16.1% less diet that would be needed to produce the number of eggs produced by the germinated cottonseed diet plus the 34.4% reduction in the cost of the diet would be a direct savings of ca. $100/million insects. Also, indirect savings would result, because less labor would be required to produce the diet pellets and to feed fewer weevils, and

the time, labor, and salt water required to extract the eggs would be reduced. Specialized equipment such as germinating trays, racks for holding these trays, and the roller press are not needed to prepare the new puree. Although statistical analysis of the data did not show significant differences in the number of eggs produced by the 2 diets, the reduction in cost of the cottonseed meat diet justifies its use.

524. , and Malone, O. L. 1973. Sodium benzoate and sodium propionate as anticontamination diets fed to adult boll weevils. J. Econ. Entomol. 66: 577.

The smallest doses did not significantly change the mean number of eggs per female per day from that obtained with the standard diet. However, when 0.326% sodium benzoate or 2.43% sodium propionate was added, the mean number of eggs per females per day increased to 14.2 and 12.3, respectively, or 52.69 and 32.26%. Increases also occurred at the highest doses but to a lesser degree. No mortality was noted even at the highest dose during the 14 days of the test. Also, 50-egg samples collected each day for 7days from pellets containing 0.326% sodium benzoate and from the standard pellets were placed on moistened filter paper in a petri dish and checked daily for 5 days; the newly hatched larvae were removed from the petri dish and counted. The mean hatch of the eggs from the standard diet was 63.7%; that of eggs from pellets containing 0.326% sodium benzoate was 82.2%. Therefore, sodium benzoate at 0.326% has been used in the rearing program at the laboratory for almost a year with excellent results. As a result, the frastic fluctuations in egg production that had occurred have ceased, and the production of eggs is more stable and predictable.

525. ; Poe, W. E.; and Hedin, P. A. 1980. Essential amino acids in dietary protein sources and the nutritional status and oviposition of boll weevils. J. Econ. Entomol. 73: 172-175.

The content of essential amino acids in the bud anthers of cotton, Gossypium spp., the normal feeding site of Anthonomus grandis grandis (Boheman) was similar to the content in the insect. The standard adult and larval boll weevil diets possessed a lysine-arginine ratio of 0.52 because of the high level of cottonseed arginine, but the ratio in anthers (assumed to be optimal) was 1.50. Two diets that were formulated with a higher lysine-arginine ratio (0.90) and a higher total amino acid content gave increased larval survival, growth, oviposition and hatch.

526. ; Roberson, J.; and Wright, J. E. 1979. Evaluation of three larval and adult boll weevil diets. J. Econ. Entomol. 72: 450-452.

Large-scale production procedures and conditions were used to evaluate 3 diets for rearing Anthonomus grandis grandis Boheman. The Gast diet produced more adults at a lower cost than the other 2; however, with the Gast diet, adults were smallest and percent egg hatch was lowest. The high gossypol diet produced the largest adults and highest percent egg hatch. Yields of adults were lowest and cost per 1000 adults was highest with cottonseed flour diet.

527. ; Wiygul, G.; Wright, J. E.; Dawson, J. R.; and Roberson, J. 1980. Rapid method for mass-marking boll weevils. J. Econ. Entomol. 73: 385-386.

The addition of 550 ppm Calco Oil Red N-1700® dye to larval diet marked ca. 1 million adult Anthonomus grandis grandis Boheman that were reared on the diet each week. No significant differences were found in yield of adults, weight, number of eggs per female per day, or percent hatch. Also, there were no significant differences in longevity, sterility, pheromone production, or mating capability of marked and unmarked adults when fed 100 ppm diflubenzuron for 6 days and then exposed to 10 krads of gamma irradiation from a ^{137}Cs source.

528. Lindquist, D. A.; Coppedge, J. R.; Ridgway, R. L.; Cowan, C. B.; and Rummel, D. R. 1967. A preliminary report on the effectiveness of Temik sidedress treatments for overwintered boll weevil control. Tex. Agric. Exp. Stn. Dep. Entomol. Tech. Rep. 9, 19 pp.

Temik®, [a 10% granular formulation of Union Carbide 21149, 2-methyl-2-(methylthio)propionaldehyde O-(methyl=carbamoyl)oxime] applied as a side-dressing to 4 to 5-acre plots of cotton just as squaring started was effective in controlling boll weevils, Anthonomus grandis Boheman, for a period of 2 to 5 weeks. A single treatment of 2 lb. of toxicant per acre applied once was effective for 2 to 4 weeks, two treatments of 2 lb. of toxicant each applied 10 days apart were effective for 4 to 5 weeks. More bollworm (Heliothis spp.) larvae were found in treated than in untreated plots.

529. , and House, V. S. 1967. Mating studies with apholate-sterilized boll weevils. J. Econ. Entomol. 60: 368-473.

When female boll weevils, Anthonomus grandis Boheman, were mated alternatedly with normal and apholate-treated males considerable mixing of sperm occurred. Also, the second mating was more effective than the first, and sperm from the last mating prior to egg deposition to fertilize most of the eggs laid subsequently.

530. Lloyd, E. P. 1976. The Pilot Boll Weevil Eradication Experiment. Proc. Tall Timbers Conf. Ecol. Animal Control Habitat Manage., Feb. 24-Mar. 31, 1974, 58, pp. 125-133.

The Pilot Boll Weevil Eradication Experiment was conducted in 1971-1973 in South Mississippi and adjacent areas of Louisiana and Alabama. In 1973, only 33 of the 236 fields were infested in the eradication area and they were in the northern zones nearest the first buffer. Indications were that the problem was caused by migration from the second buffer where overwintering populations were considerably higher. Infested fields were treated at 3-day intervals

with azinphosmethyl. As a result of these treatments, reproduction could not be detected in 32 of the 33 fields at the end of the experiment. The infestations in the one field was not detected until the last week of the experiment so that time did not permit total elimination of reproduction in it.

531. ; Daum, R. J.; McLaughlin, R. E.; Tingle, F. C.; McKibben, G. H.; Burt, E. C.; McCoy, J. R.; Bell, M. R.; and Cleveland, T. C. 1968. A red dye to evaluate bait formulations and to mass mark field populations of boll weevils. J. Econ. Entomol. 61: 1440-1444.

Calco Oil Red N-1700 dye was used to evaluate bait formulations both in the laboratory and in the field as well as to mass mark field populations of the boll weevil, Anthonomus grandis Boheman, attracted to a cottonseed-oil bait. The red dye permitted the evaluation of bait formulations without confounding the efficacy of the bait with control agents. It was not necessary to handle the insect; the marked insect was easily recognized when captured; the dye persisted throughout the life of the individual, and the dye caused no deleterious biological effects.

532. ; McCoy, J. R.; and Haynes, J. W. 1976. Release of sterile male boll weevils in the Pilot Boll Weevil Eradication Experiment in 1972-73. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 12-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 95-102.

With a high degree of effective male sterility during a weekly release program, the accidental release of 1% females will have little if any effect on reproduction because of the high level of effective sterility in the released sterile males. The absence of ebony adults developing from larval collections during the period of weekly releases clearly indicates that the release of 1% female weevils had no effect on reproduction so long as releases were made weekly.

However, measurable ebony populations following the termination of sterile-male releases indicate (1) effective male sterility decreased as releases ended, and (2) the importance of accidently released, partially sterilized females increases when releases are terminated. If releases of sterile males had continued, a high level of effective sterility would likely have continued as well.

533. ; McCoy, J. R.; Scott, W. P.; Burt, E. C.; Smith, D. B.; and Tingle, F. C. 1972. In-season control of the boll weevil with ultra-low-volume sprays of azinphosmethyl or malathion. J. Econ. Entomol. 65: 1153-1156.

A 3-year field study showed that ultra-low-volume formulations on azinphosmethyl (0.125 lb/acre) or malathion (0.5 lb/acre), when they were applied on a 4- or 5-day schedule, gave in-season control of Anthonomus grandis Boheman.

534. ; McCoy, J. R.; Stewart, J. R.; and Torries, W. J. 1972. A portable shaker for sampling populations of overwintering boll weevils in surface woods trash. J. Econ. Entomol. 65: 1502-1503.

The new shaker is adapted from the mechanical shaker attributed to the late F. F. Bondy and is mounted on the bed of a 1/2-ton pickup truck. It eliminates packaging and unpacking crude samples, most of the grass trash is left at the collection site, which eliminates the disposal problem and the processing of samples at collection site and permits many more samples to be transported in a vehicle; ca. 20 crude samples vs. 100 processed samples, even though 1/2 the bed space is occupied by the portable shaker.

535. , and Merkl, M. E. 1966. A field-cage study of population dynamics of the boll weevil. J. Econ. Entomol. 59: 83-86.

In a 2-year replicated field-cage experiment with boll weevils, Anthonomus grandis Boheman, first-generation progeny from estimated overwintered populations of 1, 14, 25, 50 and 100 weevils per acre damaged 0, 28, 46, 66, and 83% of the squares, respectively. Second-generation weevils damaged from 84 to 96% (weevil-

free check excluded) of the squares. Seed cotton harvested from the respective treatments averaged 2902, 1875, 1678, 1318, and 847 lb per acre. Differences in lint quality were detected between plots infested with 100 overwintered weevils per acre and those infested at the other 4 levels. These differences were observed in the first and third harvesting in 1961. No other quality differences were observed.

536. ; Merkl, M. E.; Tingle, F. C.; Scott, W. P.; Hardee, D. D.; and Davich, T. B. 1972. Evaluation of male-baited traps for control of boll weevils following a reproduction-diapause program in Monroe County, Mississippi. J. Econ. Entomol. 65: 552-555.

In the spring of 1969, male-baited traps for Anthonomus grandis Boheman were placed around ca. 4000 acres of cotton in a large-scale field test in Monroe County, after completion of a voluntary grower-sponsored reproduction-diapause control program the fall of 1968. The few fields that had not been treated produced a population of weevils which varied from field to field. Where overwintered boll weevils numbered less than 5 per acre, the trap efficiency was estimated to be 93%, but it dropped to 21% when the populations averaged about 300 weevils/acre. Differences in the number of overwintered boll weevils collected per trap were not significant when 1, 2, 4, and 8 traps per acre were compared. However, significantly more overwintered boll weevils were found in the fields with 8 traps per acre than in fields with 2 traps per acre. Interfield movement of overwintered weevils from the fields that had not been treated with the untreated fields. Interfield movement of overwintered weevils from the fields that had not been treated appeared to be restricted to those fields that shared overwintering sites with untreated fields. Some fields were treated with insecticides in July for control of 1st-generation boll weevils, but many fields did not require treatment until early August.

537. , and Scott, W. P. 1976. Intensive sampling of twenty-five selected fields in eradication and first buffer areas of the Pilot Boll Weevil Eradication Experiment in 1973. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 108-112.

Twenty-five fields were selected in the eradication (zone I) and first buffer (zone II) areas of the Pilot Boll Weevil Eradication Experiment (PBWEE) for intensive sampling to detect the presence of low-density boll weevil populations in these fields from early June until the experiment was terminated August 10. The secondary objective of this study was to determine the relative abundance of boll weevils in the trap crops and normal plantings as the season progressed.

538. ; Scott, W. P.; Shaunak, K. K.; Tingle, F. C.; and Davich, T. B. 1972. A modified trapping system for suppressing low-density populations of overwintered boll weevils. J. Econ. Entomol. 65: 1144-1147.

Strips along 2 sides of cotton fields (about 10% of the field) were treated with 2 sidedress applications of aldicarb (2 lb per acre per application), and sterile male Anthonomus grandis Boheman, with their wing covers glued together to restrict movement, were released on adjacent untreated cotton plants to provide a natural source of pheromone which would attract the overwintered native population to the treated strips, where they would be killed. This system suppressed the population below damaging levels longer than standard sticky male-baited wing traps. Also, it protected the natural predators and parasites of the bollworm, Heliothis zea (Boddie), in the untreated portion of the fields. Three of the 30 strips (about 4 acres of cotton) had to be treated to control bollworms after the 2nd sidedressing of aldicarb. The remainder of the fields did not require insecticides for control of bollworms until late in the season.

539. ; Tingle, F. C.; and Gast, R. T. 1967. Environmental stimuli inducing diapause in the boll weevil. J. Econ. Entomol. 60: 99-102.

In laboratory studies conducted at Stoneville and State College, Mississippi, 5 environmental stimuli induced diapause in the boll weevil, Anthonomus grandis Boheman: 1) exposure to an 11-hour photoperiod in the larval and pupal stages; (2) exposure to night temperatures of 10°C in the adult stage; (3) boll feeding in the adult stage; (4) limitation of the quantity of squares fed in the adult stage; and (5) boll feeding in the larval stage. Wild strains of weevil in Mississippi responded to these stimuli, but the State College laboratory strain did not.

540. ; Tingle, F. C.; McCoy, J. R.; and Davich, T. B. 1966. The reproduction-diapause approach to population control of the boll weevil. J. Econ. Entomol. 59: 813-816.

Six applications of a spray of methyl parathion (0.5 lb per acre) were made at 4-to 5-day intervals to isolated cottonfields in Carroll County, Mississippi, to control reproducing and diapausing boll weevils, Anthonomus grandis Boheman, during the fall. The most effective followup procedure included chemical defoliation of cotton plants to limit the available weevil food, and a final application in October of Bidrin® (3-hydroxy-N, N-dimethyl-cis-crotonamide dimethyl phosphate) at 1 lb per acre. Examination of seedling cotton from the treated fields the following spring indicated that in 1 field only 2.7 weevils per acre had survived the control program and the winter weather. The boll weevil population in the treated fields did not rise to damaging proportions until mid-August (the 2nd generation).

541. ; Tingle, F. C.; Merkl, M. E.; Burt, E. C.; Smith, D. B.; and Davich, T. B. 1967. Comparison of three rates of application of ultra-low azinphosmethyl in a reproduction-diapause control program against the boll weevil. J. Econ. Entomol. 60: 1696-1699.

Azinphosmethyl applied as an ultra-low-volume spray at 0.2 and 0.25 lb per acre was as effective as a water-emulsion spray of methyl parathion (0.5 lb per acre) in a reproduction-diapause control experiment conducted in Carroll County, Mississippi, against the boll weevil, Anthonomus grandis Boheman. A lower rate of azinphosmethyl, 0.125 lb per acre, was less effective. Populations of boll weevils sampled in woods trash adjoining treated and untreated fields were reduced 94% the fall of 1965 and 98% the spring of 1966.

542. ; Wood, R. H.; and Mitchell, E. B. 1977. Boll weevil: suppression with TH-6040 applied in cottonseed oil as a foliar spray. J. Econ. Entomol. 70: 442-444.

In the laboratory, Thompson-Hayward TH-6040 (N-4-chlorophenyl)-N-(2,6-difluorobenzoyl)urea) formulated in cottonseed oil and applied to cotton plants was effective in preventing hatch of eggs laid by female Anthonomus grandis Boheman for 4-7 days after the females were exposed. In the field, TH-6040 (0.25 AI/acre) in cottonseed oil applied every 4 to 5 days from initiation of squaring in mid-June until late Aug. either caused all eggs to fail to hatch or caused emerging larvae to die in the 1st instar. As a result, no 1st field-generation boll weevils could be detected by in-field trapping until Aug. 20. Even then, the population was very low and could be attributed partially to rainfall that washed off 2 successive treatments of TH-6040 in late July.

543. Lopez, J. D., Jr. 1980. Comparison of two types of boll weevil pheromone traps to monitor seasonal response. J. Econ. Entomol. 73: 324-326.

The relative efficiency of Leggett and Story® pheromone traps in capturing Anthonomus grandis grandis Boheman was compared in a noncompetitive situation in central Texas. The pattern of seasonal response of the boll weevil to the traps was similar to that reported in other areas. Throughout the growing

season, Leggett traps were significantly more efficient than Story traps.

544. ; Witz, J. A.; Hartstack, A. W., Jr.; and Hollingsworth, J. F., Jr. 1978. Response of the male boll weevil to grandlure. Southwest. Entomol. 3: 124-129.

When laboratory-reared male boll weevils, Anthonomus grandis Boheman (Coleoptera: Curculionidae), were released around a grandlure-baited Leggett trap, it was found that the starved weevils were recovered in greater numbers than fed weevils, and that starved weevils not exposed to high concentrations of the synthetic pheromone were more responsive than those exposed. This suggests that food availability through its effect on male boll weevil pheromone production is an important factor in the male aggregating response and this effect may at least in part be used to explain the seasonal response pattern of male boll weevils to pheromone-baited traps.

545. Lue, P. S.; Watson, J. E.; and Gilliland, F. R., Jr. 1973. Karyology of the boll weevil. Ann. Entomol. Soc. Am. 66: 801-802.

A karyotypic study of Anthonomus grandis Boheman based on germinal and somatic tissue revealed a diploid chromosome number of 22. The eleven pairs of chromosomes were classified into three morphological groups.

546. ; Watson, J. E.; and Gilliland, F. R., Jr. 1976. Karyotypic determination in the boll weevil. J. Hered. 67: 308-312.

The karyotype of the boll weevil was determined to contain 11 pairs of chromosomes separable into three metacentric pairs, among the nine autosomal pairs; and a pair of submetracentrics (X's) and another pair of acrocentrics (Y's), among the the sex chromosomes pairs. This compound sex determining system ($X_1X_2Y_1Y_2$) agrees with the mechanism reported for several other coleopterans.

547. Lukefahr, M. J., and Maxwell, F. G. 1969. The differential resistance mechanism in female Hampe. sp. trees to the boll weevil. Ann. Entomol. Soc. Am. 62: 542-544.

Numerous adult Anthonomus grandis Boheman (Coleoptera: Curculionidae), emerged from infested buds collected from the male tree of the dioecious species Hampea sp., but no weevils emerged from about 1000 female buds. Dissection of infested female buds and periodic observations of male and female trees near Martinex de la Torre, Veracruz, Mexico, between September 1966 and August 1967 revealed a unique mechanism of resistance in the female tree that discourages selection by adult female boll weevils and prevents subsequent development of the larvae.

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548. McCarty, J. C., Jr.; Jenkins, J. N.; and Parrott, W. L. 1977. Boll weevil resistance, agronomic characteristics, and fiber quality in progenies of a cotton cultivar crossed with 20 primitive stocks. Crop Sci. 17: 5-7.

Primitive race stocks of cotton (Gossypium hirsutum L.), were crossed and backcrossed twice to the recurrent cultivar 'Deltapine 16'. These progenies were evaluated for boll weevil (Anthonomus grandis Boheman), oviposition suppression in 1973, 1974 or both, and for agronomic characteristics and fiber quality in 1973. Lines were grown in replicated field tests, and oviposition was measured weekly during the fruiting period under boll weevil infestations. T-25B-58 (BC_2F_2), and T-209 (BC_2F_2) had significantly less oviposition than the control, Deltapine 16 in 1973. Resistance is in diverse genetic stocks of cotton, which might be of economic importance. The agronomic characteristics and fiber properties of the progenies have rapidly approached those of commercial cultivars. Since no character associated with the primitive race stock adversely affected agronomic quality, these lines might be useful in the development of boll weevils resistance cottons if satisfactory yields could be obtained.

549. ; Jenkins, J. N.; Parrott, W. L.; and Davich, T. B. 1972. Effect of dyes on body fat and eye color of ebony pearl boll weevils. J. Econ. Entomol. 65: 370-373.

Different marking techniques for Anthonomus grandis Boheman were tested. Ebony pearl individuals were reared on larval media containing 1000 ppm of the following dyes: (1) Calco Oil Red N-1700®; (2) Acridine Orange; (3) Eosin-Bluish; (4) Sudan II; and (5) Nile Blue A. Calco Oil Red N-1700 was the only dye which sufficiently dyed the eye and body fat of emerging adult weevils. Adult ebony pearl weevils were fed adult media plugs for 6 days containing Calco Oil Red N-1700 in the media or wax covering, or media and wax covering of plugs. Body fat of the weevils was dyed red, but the eyes were unmarked. Dye (5000 ppm) in the wax covering of plugs also dyed the body fat, but not the eye. Ability to obtain 2 different markers, body fat and eyes or body fat only, depends upon whether the dye is fed to larvae or adults.

550. McClendon, R. W.; Mitchell, E. B.; Jones, J. W.; McKinion, J. M.; and Hardee, D. D. 1976. Computer simulation of pheromone trapping systems as applied to boll weevil population suppression: a theoretical example. Environ. Entomol. 5: 799-806.

An analysis of a pheromone trapping system was performed to study the possibility of theoretically estimating the efficiency of a boll weevil pheromone field trapping system. Release-capture data for a single trap were used to establish percent capture versus distance from the trap. A computer simulation model predicting trapping efficiency showed that results are very sensitive to the responsiveness characteristics of the population. Theoretical results also showed sensitivity to trap spacing and identified some specific research needs.

551. McCoy, J. R. 1975. Phenotypic deviants in the ebony genotype in the boll weevil. J. Econ. Entomol. 68: 775-776.

Three pheno-deviations of the ebony genotype isolated from a reproducing field population of ebony boll weevils, Anthonomus grandis Boheman, were described. Studies of the F_1, F_2, and backcross progenies indicated that these deviations are not genetically controlled but rather the result of variable expressively of the ebony genotype.

552. . 1979. High-insert: a dominant mutant in the boll weevil with recessive lethal effect. J. Hered. 70: 349-350.

An autosomal, dominant lethal mutant of the boll weevil, high-insert, is described. This mutation is characterized phenotypically by having the antennal insertion much nearer the eyes than normal. Matings between high-insert and nonmutants result in a 1:1 mutant-nonmutant ratio, and mutant/mutant matings yielded a 2:1 mutant-nonmutant ratio. In addition more than one-half of the mutant females failed to oviposit.

553. , and Lloyd, E. P. 1975. Evaluation of airflow systems for the collection of boll weevils from cotton. J. Econ. Entomol. 68: 49-52.

To develop a more rapid and efficient mechanical method of detecting low level infestations of Anthonomus grandis Boheman, 4 mechanical collection systems were compared with visual observation of adult boll weevils in cotton. The McCoy Insect Collector (a dual directional blower and vacuum system) was the most efficient system and had an efficiency of 130% compared with visual detection. Field tests indicate that ca. 10% of the oviposition damaged squares on the plants as well as adult weevils will be collected with the mechanical sampling device. The McCoy Insect Collector is capable of detecting the presence of 2 adult weevils in 10 acres of cotton whether by collection of the weevils or by collection of infested squares.

554. ; Lloyd, E. P.; and Bartlett, A. C. 1968. Diapause in crosses of a laboratory and a wild strain of boll weevils. J. Econ. Entomol. 61: 163-166.

A strain of boll weevils, Anthonomus grandis Boheman, with a high ability (more than 35%) to diapause (M) was crossed in the laboratory with a strain (S) with a low ability (less than 5%) to diapause. Analysis of data from the 2 strains and progeny from the reciprocal parental crosses showed 3 statistically different sets of percentages of diapause: the M strain had a high percentage; the S strain had a low percentage; and the reciprocal F_1 progeny had percentages approaching that of the S strain. When the pure strain, F_2, and backcross progeny were exposed to diapause-inducing stimuli, the means of the percentage of weevils attaining diapause fell into 4 statistical sets: the M strain, the backcrosses to the M strain and the F_2 from (S x M) x (S x M), the F_2 from (M x S) x (M x S) which was not significantly different from the least responsive M backcross and the most responsive S backcross, and the backcrosses to the S strain. The percentages of diapause attained by the backcrosses to the S strain were not significantly different from those of the S strain. These results indicated partial dominance and possible simple inheritance of alleles that suppress diapause in the S strain. The use of insects genetically incapable of attaining diapause for a sterile-insect-release program would minimize concern that some released insects might not be sterilized because nondiapausing insects could not survive the winter and their matings to wild weevils would greatly reduce the ability of progeny to attain diapause.

555. , and Wright, J. E. 1979. Evaluation of bisazir and penfluron as sterilants for the boll weevil. Southwest. Entomol. 4: 209-215.

Adult boll weevils, Anthonomus grandis Boheman, of defined ages of 1, 2, 3, 4, 5, 6 and 10 days were fumigated with bisazir (P, P-bis (1-aziridinyl)-N-methylphosphinothioic amide) at atmospheric pressure for 30, 60, 90, 120, and 180 min.

(2, 6-difluoro-N-[[[4-(trifluoromethyl)phenyl]amino]carbaryl]benzamide) in acetone. When the treatments were combined for 100,000 adults of mixed sexes, the sterility level was 99±% when fumigation time was 90 min or more and the age of the weevils at the time of treatment made little difference in the resulting sterility level. Bisazir is a male sterilant, and penfluron inhibits the reproductive potential of females, and both must be used to obtain sterility when mixed sexes are treated.

556. McGarr, R. L., and Chapman, A. J. 1966. Initial field tests with methyl parathion and EPN in Mexico against the boll weevil. J. Econ. Entomol. 59: 1529.

Methyl parathion is now probably the insecticide most widely used for cotton insects in the Western hemisphere. EPN (O-ethyl O-p-nitrophenyl phenylphosphonothioate) though effective against several cotton insects has not been used extensively. This report describes the 1st field tests with these insecticides against the boll weevil, Anthonomus grandis Boheman, near Manuel, Tamaulipas, Mexico, in the winter of 1951-52. The early information on the performance of the compounds was used when experiments were planned at laboratories in the United States for the 1952 growing season. The record has historical value and the data should be made available to permit later determination of any resistance that boll weevils in this area may have developed to these insecticides.

557. , and Wolfenbarger, D. A. 1968. Aerial applications of ultra-low-volume methyl parathion for control of cotton insects. J. Econ. Entomol. 61: 1107-1108.

In four field tests in the lower Rio Grande Valley of Texas methyl parathion applied at 1.0 to 1.5 lb per acre in an ultra-low-volume spray gave good control of the bollworm, Heliothis zea, the tobacco budworm, H. virescens and the boll weevil, Anthonomus grandis. The average yield in seed cotton/acre was 2544 lbs in the treated plots compared with 1066 lbs in the untreated plots.

558. , and Wolfenbarger, D. A. 1969. Methyl parathion, toxaphene, and DDT used alone and in combinations for control of several cotton insects. J. Econ. Entomol. 62: 1249-1250.

The 3-way mixture of toxaphene + DDT + methyl parathion gave the best control of tobacco budworm, pink bollworm, and the highest increase in yield. Toxaphene + methyl parathion, toxaphene + DDT and DDT + methyl parathion were about equally effective. However, none of the treatments gave adequate control. Toxaphene, DDT, and methyl parathion used alone were ineffective, none of the treatments reduced significantly the percent squares infested by the boll weevil.

559. , and D. A. Wolfenbarger, D. A. 1970. Insecticides for control of four cotton insects in 1968. J. Econ. Entomol. 63: 1324-1325.

In Test 1, EPN gave the best control of the tobacco budworm and bollworm. EPN + methyl parathion, methyl parathion, and toxaphene + DDT + methyl parathion were less effective and malathion + methyl parathion was ineffective. However, none gave adequate control of these 2 insects and the boll weevil. The mixture of toxaphene + DDT + methyl parathion gave the best reduction of light populations of pink bollworms. In Test 2, General Chemical GC-6506 (dimethyl p-(methylthio) phenyl phosphate), DuPont 1642 (methyl N-(carbomoyloxy) thioacetimidate), carbofuran, VCS-506 (O-(4-bromo-2-5-dichlorophenyl) O-methyl phenylphosphonothioate) and Union Carbide UC-34096 (4-[[(dimethylamino) methylene]amino]-intolyl methylcarbamate hydrochloride), and methyl parathion did not give adequate control of the bollworm and tobacco budworm but all of the materials reduced the infestations of boll weevils below that of the check. In Test 3, all insecticides gave a significant increase in yield over check though methyl parathion EPN was significantly better than all other insecticides and methyl parathion produced better yields than methyl parathion + parathion, monocrotophos alone, or monocrtophos + methyl parathion.

560. McGovern, W. L., and Cross, W. H. 1974. Oviposition of a parasite, Bracon mellitor, attacking larvae of the boll weevil inside a cotton square. Ann. Entomol. Soc. Am. 67: 520-521.

The oviposition of Bracon mellitor on larvae of the boll weevil has been observed in open petri dishes. A new technique made possible for observation in detail the natural act of oviposition of these parasites on boll weevil larva inside a cotton square (flower bud) under a binocular microscope.

561. , and Cross, W. H. 1976. Effects of two cotton varieties on levels of boll weevil parasitism (Col.: Curculionidae). Entomophaga 21: 123-125.

The cotton plant has a profound effect on the behavior and ability of parasites to successfully attack the boll weevil, Anthonomus grandis Boheman. The most important native parasite of the boll weevil, Bracon mellitor Say, prefers to oviposition Frego bract cotton rather than normal bract cotton. An imported parasite, Heterolaccus grandis Burks prefers ovipositions on normal bract cotton rather than Frego.

562. ; Cross, W. H.; and Harris, W. 1975. Implications of early emergence of Bracon mellitor, a parasite of the boll weevil. J. Ga. Entomol. Soc. 10: 183-186.

Bracon mellitor Say, the most important parasite of the boll weevil, Anthonomus grandis Boheman, was found to emerge very early in the season. Therefore, an alternate host is required if the parasite is to survive until squares infested with boll weevils are available for parasitization.

563. ; Cross, W. H.; Leggett, J. E.; Hardee, D. D.; McKibben, G. H.; and Johnson, W. L. 1974. Mutants of the boll weevil as genetic markers: abnormal field behavior of an ebony pearl strain. J. Econ. Entomol. 67: 701.

Results indicated that the pearl eye strain should be eliminated as a culture

for mass-rearing purposes. There would be little point in keeping the strain and dying it red since the purpose of genetic markers is to avoid mechanical marking. However, the improved response when dye was incorporated in the area of the eye did indicate that the poor performance of the strain results from the gene for pearl eye and from the gene for ebony body color.

564. ; Cross, W. H.; Leggett, J. E.; McKibben, G. H.; Johnson, W. L.; McCoy, J. R.; and Haynes, J. W. 1976. Boll weevils: field competitiveness among several laboratory strains, chemosterilized weevils, and field weevils. Environ. Entomol. 5: 354-356.

Male boll weevils, Anthonomus grandis Boheman, reared in the laboratory and sterilized with busulfan (1, 4-butanediol dimethan-sulfonate) alone were more attractive to ♀ weevils than those treated with combinations of busulfan and hempa. In general, sterilization reduced the attractiveness of laboratory-reared males by ca. 50%. Evidence is presented that shows a great range of variability in the attractiveness of males of 1 type. These sterilized ♂ boll weevils are as attractive to ♀ weevils as overwintered field males.

565. ; Cross, W. H.; Leggett, J. E.; and Mitlin, N. 1973. Boll weevils: a technique for measuring the production of pheromone and the competitiveness of ^{32}P tagged adults in the field. J. Econ. Entomol. 66: 809.

The sterile-male technique, is an integral part of many insect-eradication programs, and it is considered by most scientists to be the key factor in the eradication program currently in progress against the boll weevil, Anthonomus grandis Boheman. Therefore, in anticipation of this portion of the program, a reliable method was needed to compare the production of pheromone and the sexual competitiveness of sterile and native weevils in the field. In our search for such a method, we used the technique for marking overwintering boll weevils with ^{65}Zn. However, our tests were to

be of short duration, so ^{32}P was used instead. Also, the weevils were individually marked.

566. ; Cross, W. H.; and Mitchell, H. C. 1974. Eupelmus cyaniceps (Hymenoptera: Eupelimidae), a hyperparasite. J. Ga. Entomol. Soc. 9: 68-69.

Eupelmus cyaniceps, previously believed to be a primary parasite of the boll weevil, was found instead to be a hyperparasite of Bracon mellitor.

567. ; Hardee, D. D.; and Davich, T. B. 1969. Chemosterilants applied as sprays against populations of boll weevils in cotton in field cages. J. Econ. Entomol. 62: 1144-1147.

In the first large-scale tests with sprays of chemosterilants against any insect pest, apholate applied to the cotton in 2 1/2-acre screened cages at rates of 1, 2, or 4 pounds per acre for control of Anthonomus grandis Boheman suppressed populations compared with an untreated check whether the initial infestations were begun with virgin or mated pairs. Hempa, at a rate of 2 lb per acre, was ineffective. At 4 lb per acre, apholate reduced production of squares compared with an untreated check, but the toxicity of this compound was too great for general use. Since the technique proved effective, other less hazardous chemosterilants are being sought.

568. ; Leggett, J. E.; Johnson, W. L.; and Cross, W. H. 1973. Technique for separating boll weevils and other insects from samples taken with an insect collecting machine. J. Econ. Entomol. 66: 1332.

Studies of the dispersal of the boll weevil, Anthonomus grandis Boheman, require capture, marking, and release of large numbers. Reported here are 2 techniques for recovering boll weevils from field samples obtained by insect-collecting machines. These machines are the result of several modificiations and improvements of the Nisbet bug catcher and modified high-clearance sprayers.

569. ; McKibben, G. H.; Cross, W. H.; Essig, H. W.; and Lindig, O. H. 1976. Boll weevil: square ingestion or utilization studies. Ann. Entomol. Soc. Am. 69: 738-739.

Laboratory-reared ♂ boll weevils, Anthonomus grandis Boheman, ate ca. 13 mg of squares per day though field-collected weevils ate only 10 mg per day; however, the field weevils were 9% more efficient in the utilization of squres. Laboratory weevils utilized 23% of nitrogen consumed. They digested 5.5 cal/day, which means that ca. 49% of the energy consumed was metabolized.

570. ; McKibben, G.; Cross, W. H.; and Haynes, J. 1975. Cotton squares: increase in density after oviposition by the boll weevil and its possible implication. J. Econ. Entomol. 68: 207-208.

Cotton squares containing an egg deposited by Anthonomus grandis Boheman were significantly denser than cotton squares for did not contain an egg. This increased density may cause mortality of the egg stage.

571. ; McKibben, G. H.; Gueldner, R. C.; and Cross, W. H. 1975. Irradiated boll weevils: pheromone production determined by GLC analysis. J. Econ. Entomol. 68: 521-523.

The production of pheromone by Anthonomus grandis Boheman when treated with 10,000 rad of CO-60 gamma irradiation compared favorably with that of control weevils for 5 days; however, feeding (determined by frass collection) was reduced from day one. No direct correlation was found between production of pheromone and elimination of frass.

572. ; McKibben, G. H.; Johnson, W. L.; Merkl, M. E.; and Cross, W. H. 1976. Pheromone production by overwintered boll weevils. Environ. Entomol. 5: 101-102.

Overwintered ♂ boll weevils, Anthonomus grandis Boheman, were found to produce only very small quantities of pheromone. Also, the ratio of the 4

components in the pheromone of these weevils differed from that in the standard formulation of grandlure and was less attractive. Consequently, even sterilized laboratory weevils should be more attractive than overwintered males.

573. ; Mitchell, E. B.; and Cross, W. H. 1978. Improved technique for tagging boll weevils with ^{32}P. J. Ga. Entomol. Soc. 13: 24-28.

Weevils can now be easily and safely radioactively tagged by placing them behind a piece of clear lead glass and using an electrically driven microapplicator controlled by a foot switch and a shielded syringe to dispense the material. The weevils are first anesthetized with CO_2 and then picked up with a vacuum controlled pipette by using a foot operated solenoid switch. Tagged weevils were detectable at 35 to 86 cm where weevils are tagged with 0.84 - 3.33 μCi/weevil.

574. MacGown, M. W., and Sikorowski, P. P. 1980. Histopathology of midgut of mass reared, irradiated boll weevils contaminated with Staphylococcus aureus and Streptococcus sp. J. Econ. Entomol. 73: 81-87.

Bacterial contamination and irradiation cause rapid deterioration of midgut epithelium of Anthonomus grandis grandis Boheman. Staphylococcus aureus Rosenback and Streptococcus sp. greatly accelerate the effects of irradiation, resulting in destruction of the tissues within a few days. The bacterial damage to the midgut causes premature mortality of the boll weevils.

575. McHaffey, D. G., and Borkovec, A. B. 1976. Vacuum dipping: a new method of administering chemosterilants to the boll weevil. J. Econ. Entomol. 69: 139-143.

Sterility in both sexes of Anthonomus grandis Boheman resulted when adults were dipped for 5 sec in certain chemosterilant solutions of pressures of 175 mmHg or less. Effective compounds were tris (1-aziridinyl) phosphine

sulfide (A13-24916, thiotepa) and P,P-bis (1-aziridinyl)-N-methylphosphinothioic amide (A13-61585). The vacuum-dip technique could easily be scaled-up for a mass treatment program.

576. ; Flint, H. M.; Haynes, J. W.; Klassen, W.; Mitlin, N. and Davich, T. B. 1972. Sterility induced in boll weevils by alkylating agents administered in an adult diet. J. Econ. Entomol. 65: 13-19.

The chemosterilant activity of 4 alkylating agents to adult Anthonomus grandis Boheman was investigated. A diet containing 0.1% busulfan (1,4-butanediol dimethanesulfonate or ENT 25012) and fed for 6 days produced sterility in both sexes in 5 out of 7 tests. Busulfan 0.2% for 6 days and 0.4% for 4 days generally were effective against both sexes, but mortality was high in the male. Although ENT 61168 (diethylene glycol dimethanesulfonate) was ineffective against the male, this compound generally sterilized the females at either 0.4% for 4 and 6 days ro 0.8% for 4 days. ENT 51904 (1,3-propanediol dimethanesulfonate) was ineffective against the male, but all regimes produced sterility in the female. Apholate produced sterility in both sexes only when accompanied by excessive mortality.

577. McKibben, G. H. 1972. A device for injecting grandlure into cigarette filters. J. Econ. Entomol. 65: 1509-1510.

In the past 2 years, large numbers of grandlure pellets were prepared at the Boll Weevil Research Laboratory, State College, Miss., for traps used in surveying and studying the boll weevil, Anthonomus grandis Boheman. Originally, pellets were prepared by manually pipetting 0.5 ml of grandlure solution onto cigarette filters. The procedure was slow, only ca. 500/hr could be compeleted, and considerable variation existed among doses dispensed by technicians. Moody et al. (1972) constructed a device in which a solenoid-driven syringe was used to dispense the solution: filters were put into stems

of funnels placed around the periphery of a turntable. At a certain point in the rotation, each funnel contacted a microswitch that actuated the solenoid which delivered the liquid into the stem of the funnel by depressing the syringe plunger through a lever. The grandlure was then absorbed by the filter. I subsequently constructed a device that is somewhat faster and is easier to assemble. The same principle is used, but the pipetting syringe is operated horizontally and is fitted with an 18-gauge needle that injects the solution of grandlure into the filters. Filters are injected at a rate of ca. 3000/hr with a variation in dose of ca. ±2%.

578. . 1974. An improved device for dispersing pheromone solutions. J. Econ. Entomol. 67: 558.

A machine for dispensing grandlure (the synthetic pheromone of the boll weevil, Anthonomus grandis Boheman) into cigarette filters that involved the use of a solenoid-driven syringe was built by Moody. McKibben built a similar machine that produced about 3000 treated filters/h. A further improvement eliminated the solenoid to drive the syringe but retained the injection principle. In one year the improved machine injected 330,000 filters with no major parts failures.

579. , and Davich, T. B. 1977. Air dropped bait dispensers for attracting and killing the cotton boll weevil. U.S. Patent No. 4,027,420.

A new apparatus and method for attracting and killing cotton boll weevils is disclosed. Specifically this apparatus consists of a toxic material affixed to a substrate which is air dropped onto fields of growing cotton. Boll weevils are attracted to these air dropped baited traps and killed upon contact.

580. ; Davich, T. B.; Gueldner, R. S.; Hardee, D. D.; and Hedin, P. A. 1974. Polymeric compositions for attracting cotton boll weevils. U.S. Patent No. 3,803,303.

A synthetically prepared boll weevil sex attractant, two natural plant attractants, and an insect repellent have been formulated so as to include certain glycols and/or derivatives thereof. These formulations, in the form of attractant-containing pellets have been successfully employed to trap and destroy boll weevils for periods up to one week. Because these new formulations are designed to release the active ingredients at controllable rates the effectiveness of the active ingredients is sustained for longer periods of time than those attained in the prior art.

581. ; Hardee, D. D.; Davich, T. B.; Gueldner, R. C.; and Hedin, P. A. 1971. Slow-release formulations of grandlure, the synthetic pheromone of the boll weevil. J. Econ. Entomol. 64: 317-319.

Results of field tests with grandlure, the pheromone of the boll weevil, Anthonomus grandis Boheman, showed it to be a potent attractant, though preliminary work by Hardee has shown it to have a very short residual life. We therefore needed to find a way to extend its activity. Whitlaw and Evans screened plastic and resin materials as slow-release agents for mosquito larvicides and reported that polyamide and other resins extended activity. We tested these and other selected materials at the Boll Weevil Research Laboratory at State College, Miss., to find a sustained, slow-release preparation in a form that could be used in the field.

582. . 1976. Composition for attracting the boll weevil. U.S. Patent No. 3,954,968.

A synthetically prepared boll weevil attractant has been formulated so as to include crude cottonseed oil. This formulation, in the form of a gelled emulsion, has been used to trap and destroy boll weevils for periods up to 2 weeks. The new formulation releases the active ingredients at a more favorable rate and is effective for longer periods than previously developed ones.

583. . 1977. A new thixotropic oil formulation for sticky traps for boll weevils. J. Ga. Entomol. Soc. 12: 93-96.

A new thixotropic oil formulation has several advantages over conventional formulations, primarily because it is non-tacky and non-stringy. A cheap and effective trap for Anthonomus grandis Boheman was produced by applying the formulation to posterboard squares.

584. , and Davich, T. B. 1975. Air-dropped boll weevil bait dispensers. Miss. Agric. For. Exp. Stn. Res. Rep. 12, 5 pp.

Grandlure baited traps coated with a sticky material have been used for several years in surveys and migration studies of the boll weevil, Anthonomus grandis Boheman. A later trap captured weevils alive in a plastic container at the top of a paper cone. Then an in-field live trap placed within cotton fields was developed for detection and suppression studies. In the search for a low-cost device for containing grandlure to attract weevils to a toxic bait, we designed one that consisted of two 7-inch squares of 26-inch poster board connected by a 12 inch long string and another of two cardboard tubes of the type used for trapping gypsy moths Porthetria dispar (L.), also, connected by a string. The string improved aerodynamics balance when dropped or tossed into the field, increasing logic on the cotton foliage. The traps contained grandlure in a polyethylene glycol-impregnated filter with one gram of toxic bait containing DDT added to the filters. Results showed that the principle was feasible though a better toxicant than DDVP is needed.

585. ; Hedin, P. A.; Davich, T. B.; Daum, R. J.; and Laseter, M. W. 1971. Addition of food acidulants to increase attractiveness to boll weevils of bait containing cottonseed oil. J. Econ. Entomol. 64: 583-585.

Eight acids, used as food acidulants, when added to cottonseed oil baits used to attract Anthonomus grandis Boh. an caused a significant increase (41-67%)

in the amount ingested compared with the standard unfortified formulation. However, there were no significant differences among the acids tested.

586. ; Hedin, P. A.; McGovern, W. L.; Wilson, N. M.; and Mitchell, E. B. 1977. A sex pheromone for male boll weevils from females. J. Chem. Ecol. 3: 331-335.

Steam distillation of frass of the female boll weevil, Anthonomus grandis Boheman, yielded an extract that was more attractive to males than to females in the laboratory. Extracts purified by TLC were attractive to males only. The active components appear to be alcohols and hydrocarbons.

587. ; Hedin, P. A.; McLaughlin, R. E.; and Davich, T. B. 1971. Development of the bait principle for control of boll weevils: addition of terpenoids and related plant constituents. J. Econ. Entomol. 64: 1493-1495.

In laboratory bioassays, several candidate attractants incorporated into a cottonseed oil bait increased the olfactory response of Anthonomus grandis Boheman 10- to 16-fold over the response to the standard unfortified bait. Also, in a 1/2-acre field-cage test, a mixture of N-borneol, rose oxide, α-pinene, and linalool oxide bait added to cottonseed oil bait that contained dye for a marker increased the response of weevils 48% before mid-September. After that period, none of the attractants elicited an increase in response.

588. , and Johnson, W. L. 1976. The use of exponential and linear decay models in the evaluation of controlled-release pheromone formulations. Bull. Entomol. Soc. Am. 22: 323-325.

A regression analysis and resulting model can provide the data needed in testing pheromone formulations, and the procedure is not difficult. A mathematical model is simply a formula that describes some phenomenon, for example, the release of a volatile pheromone or the numbers of insects captured as a function of time. However, an analysis involving decay models (models that show change

with time) entails computing some parameter such as the effective life of the test formulations.

589. ; Johnson, W. L.; Edwards, R.; Kotter, E.; Kearny, J. F.; Davich, T. B.; Lloyd, E. P.; and Ganyard, M. C. 1980. A polyester-wrapped cigarette filter for dispensing grandlure. J. Econ. Entomol. 73: 250-251.

A polyester-wrapped cigarette filter was found to be at least as effective in field tests at several locations in dispensing grandlure as the ordinary paper-wrapped filter placed inside a 1-dr glass vial. The new dispenser saved considerable time in rebaiting traps in the Boll Weevil Eradication Trial in North Carolina during 1978 and 1979.

590. ; McGovern, W. L.; Cross, W. H.; and Lindig, O. H. 1976. Search for a super laboratory strain of boll weevils: a rapid method for pheromone analysis of frass. Environ. Entomol. 5: 81-82.

Three laboratory strains of boll weevils, Anthonomus grandis Boheman, produced more pheromone than the standard laboratory strain. Soxhlet extraction of the frass provided a rapid method of analyzing for the pheromone.

591. ; Mitchell, E. B.; Scott, W. P.; and Hedin, P. A. 1977. Boll weevils are attracted to volatile oils from cotton plants. Environ. Entomol. 6: 804-806.

The volatile oil obtained by distilling cotton plants was attractive both to emerging overwintered boll weevils, Anthonomus grandis Boheman, and to late-season migrating weevils in the field. The evidence indicates that the volatiles from cotton plants influence the migratory behavior of boll weevils and also are sufficiently attractive to guide overwintered boll weevils to fields of seedling cotton.

592. ; Mitlin, N.; Haynes, J. H.; and Davich, T. B. 1972. Feeding stimulants added to diet adult boll weevils. J. Econ. Entomol. 65: 1190.

In studies to determine whether additives or other ingredients would increase the ingestion of the adult boll weevil diet used at this laboratory, several additives increased initial ingestion but total ingestion was not affected.

593. McLaughlin, R. E. 1966. Infection of the boll weevil with Mattesia grandis induced by a feeding stimulant. J. Econ. Entomol. 59: 909-911.

Spores of Mattesia grandis McLaughlin were applied in a feeding stimulant formulation to cotton plants to induce boll weevils, Anthonomus grandis Boheman, to ingest infective doses. Water suspensions of spores without the stimulant infected only 1 of 162 weevils in a field test. Formulation in the form of viscous liquid and granules that contained sugar, agar, feeding-stimulant extracts from cotton squares, and spores were tested in 30X30X30-inch field cages; disease incidence ranged from 18.3 to 93.3%. In 6X7X24-foot cages, 61.4% of the adults were diseased 10 days after the last application. In 1/8-acre cages, numbers of boll weevils on the treated plants were reduced significantly by the disease. The principle that materials which elicit a behavioral response may be employed to induce host insects to acquire infective doses of pathogens was established.

594. . 1966. Laboratory techniques for rearing disease-free insect colonies: elimination of Mattesia grandis McLaughlin, and Nosema sp. from colonies of boll weevils. J. Econ. Entomol. 59: 401-404.

Mattesia grandis McLaughlin and a microsporidian, Nosema sp., were eliminated from laboratory colonies of the boll weevil, Anthonomus grandis Boheman, by a system of "Unit Integrity" that is adaptable to rearing procedures for different species of insects, makes best use of available labor and facilities, and permits production of the largest possible disease-free colony per period of

time. The "Unit" is the most homogeneous grouping obtainable, given the incidence and characteristics of the disease; once the insects have been placed in the unit, they are handled as an entity and are separated from all other such units to reduce the danger of cross contamination. The unit used to raise a disease-free colony from weevils infected with the microsporidian was the "Family Unit" because the disease was transmitted by transovum passage; selected units were reared through the F_1 generation, and units containing no disease through adults of the F_2 generation were considered disease free. The unit used with weevils infected with M. grandis was again the Family Unit, but these larger groups were then divided into subunits and given the less strenuous treatment of 10-day quarantine. The system produced larger numbers of healthy insects more quickly than selection of progeny from single pairs of weevils. It had the disadvantage that it was more susceptible to failure because of its design, although disease elimination was successful in the test.

595. . 1967. Development of the bait principle for boll-weevil control. II. Field-cage tests with a feeding stimulant and the protozoan Mattesia grandis. J. Invertebr. Pathol. 9: 70-77.

A formulation containing spores of the protozoan Mattesia grandis and a feeding stimulant made from cottonseed oil and a water extract of cotton squares plus carrier materials and a marking dye was tested against a population of the boll weevil, Anthonomus grandis, on cotton in 1/16-acre field cages, Effectiveness of the formulation was judged by the percentage of marked weevils and the incidence of disease among adults collected at the end of the test. Twenty to 30% of the treated population was marked during the main fruiting period, which is also the period of rapid development of the boll-weevil population, and 50% to 60% during the latter part of the test when the plants were maturing and fewer weevils were developing because of cooler temperatures. At the end of the test, 55% of the weevils were diseased. The diseased population produced about half

as many adults as the check population. The treated adult population remained stabilized; the check had sharply defined, eruptive increases in number of adults as each generation emerged from squares or bolls. A feeding stimulant with spores or other effective agents might be effective in reducing populations in large open fields.

596. . 1969. Glugea gasti sp. n., a microsporidan pathogen of the boll weevil Anthonomus grandis. J. Protozool. 16: 84-92.

Glugea gasti sp. n., a microsporidan pathogen of Anthonomus grandis Boheman (the boll weevil), is described and a probable life cycle presented. The alimentary canal, and probably the mesenteron 1st, is the initial site of infection, although the disease later becomes generalized throughout most body tissues. Binucleate sporoplasms initiate the 1st schizogonic phase, characterized by mono- and binucleate schizonts. The 2nd schizogonic phase is characterized by mono-, bi- and quadrinucleate schizonts, by prolific multiplication, by the dense compact nuclei early in this phase, and late in this phase by larger schizonts with less dense vesicular nuclei. This phase terminates in formation of diplokarya. The sporogonic phase is characterized by combination of the 2 nuclei in the diplokaryon followed by nuclear divisions in a sequence closely resembling meiosis. Two sporoblasts are produced from each sporont. Mature spores in wet mounts by phase contrast were 4.3 ± 0.3 μ long by 2.3 ± 0.2 μ wide. The polar filament averaged 76 μ long. Mature spores were present about 24 hours after infection. Some observations are presented on an external filament extending from one pole of the spore to host tissue and other events during the process of spore morphogenesis.

597. . 1970. Systems of mass-rearing disease-free insects, their value to studies of diseased natural populations, with particular reference to the boll weevil. Proc. Int. Colloq. Insect Pathology Session on Dis. in Nat. and Lab. Insects Pops., IV, pp. 255-261. (Abstract in French and German).

This paper presents the fundamental principles governing disease-free rearing systems. The possible sources of contamination are categorized as: (1) the insects themselves; (2) the physical facilities and associated equipment; (3) the expendable supplies; (4) the air; and (5) the personnel. This paper presents methods for exclusion or control of contamination occurring from each of the sources. The basic plan of a model system includes three phases: (1) a stock colony that produces a quantity of the desired stage, generally, the eggs; (2) a separate handling area where the rearing media is prepared for the mass production colony; and (3) the rearing area where the mass colony is produced. This progressive unilateral movement of insects and their media, without recycling to the stock colony, guarantees preservation of the integrity of the colony and its descendants. The author provides a plan and specific details of a facility for mass rearing of the cotton boll weevil, Anthonomus grandis Boh. This system posesses the capability for extremely regular and reliable production from the colony of five million adults per week.

598. . 1976. Development of feeding formulations for boll weevil: effect of ratios of cottonseed oil to invert sugar on quantity ingested and initiation of a feeding response. J. Econ. Entomol. 69: 374-376.

The importance of ratios of cottonseed oil to invert sugar in formulations of bait used against Anthonomus grandis Boheman was evaluated by determining the effect on weevil feeding responses and quantity ingested. Previous baits using water as a major quantity and occasionally with fumaric acid added were compared

to the new baits. Addition of fumaric acid gave no clear improvement in either the percentage of the weevils that started to feed or in an increase in total amount eaten per feeding individual. The 100% oil bait had the greatest ingestion response and was equaled statistically by other high oil baits. The greatest difference between formulations was seen with initiation of feeding. The percentage of weevils that started to feed was positively correlated to increased concentrations of invert sugar. Therefore, the best field formulations must be a balance between the percentage of the population that can be induced to feed on the bait and the total amount eaten by an individual weevil when the pathogen or chemical must be eaten in order to kill the insect. The desired goal is that of getting enough of the population to eat a killing dose of the bait in order to produce an acceptable reduction of the population.

599. . 1976. Response of the boll weevil to TH 6040 administered by feeding. J. Econ. Entomol. 69: 317-318.

When the IGR, Thompson-Hayward 6040 (N-(4-chlorophenyl) -N'-(2, 6-difluorobenzoyl) urea), was fed to adult ♀ Anthonomus grandis Boheman for 24 h, the concentration of the chemical required to inhibit the hatch (embryonic ED_{50}) of 50% of the eggs resulting at ca. 72 h after ingestion was 431 ppm. It was 2797 ppm at ca. 216 h. The EI_{50}'s (intervals required for inhibition to decrease to 50%) were 32 h for an initial dose of 201 ppm, 62 h for 576 ppm, and 218 h for 4034 ppm. The ED_{50} of TH 6040 for an oral dose of 0.11 μg was 84 hours.

600. . 1977. Dose-responses of the boll weevil to topical formulations of TH-6040. J. Ga. Entomol. Soc. 12: 369-370.

The growth-regulating chemical, Thompson-Hayward TH-6040 (N-(4-chlorophenyl)--(2, 6-difluorobenzoyl)urea; Dimilin®, which interferes with egg hatch in adult boll weevils, Anthonomus grandis Boheman, was tested to determine the effective

dose of topical application and the effects of the carrier formulation. Doses by topical application that inhibited egg hatch were much larger than doses by ingestion. Water was an effective carrier, but crude cottonseed oil was highly effective. The effectiveness of TH-6040 increased to a maximum during the first 3 days after application, then gradually declined. This indicates that absorption through the cuticle required several days, followed by an elimination, deactivation or some other mechanism of decreasing concentrations of TH-6040 in the insects.

601. . 1978. Contact transfer of diflubenzuron (Dimilin) by boll weevils) and the relation of site of application and effect on egg hatch. Entomol. Exp. Appl. 23: 171-176.

The growth-regulating chemical diflubenzuron (tested as TH-6040, now formulated as Dimilin®), N(4-chlorophenyl)-N-(2,6-difluorobenzoyl)urea) was (1) applied to tarsi or to genital sternites of male or female boll weevils, Anthonomus grandis Boheman, that were then placed with untreated weevils of the opposite sex; (2) applied to genital sternites of either males or females and then placed with the egg-laying females; (3) placed directly on the genital sternites of egg-laying females; or (4) applied directly to the soft integument under the elytra. TH-6040 applied to the soft dorsal integument produced a higher level of inhibition of egg hatch than did tarsal contact treatment. Application to males had a distinct effect but much smaller, on egg hatch of eggs from their mates than did direct application to the females. Application to hard cuticle (genital sternites) was less effective than to soft integument (i.e., there was less inhibition of hatch, and the rate of recovery was faster).

602. , and Adams, C. H. 1966. Infection of Bracon mellitor (Hymenoptera: Braconidae) by Mattesia grandis (Protozoa: Neogregarinidae). Ann. Entomol. Soc. Am. 59: 800-802.

The neogregarine Mattesia grandis McLaughlin infected larvae and adults of Bracon mellitor Say, a parasite of the boll weevil, Anthonomus grandis Boheman. The larvae of B. mellitor became infected by feeding on infected larvae of the boll weevil, and data suggested that any stage of M. grandis present in the host was infective. Adults of B. mellitor became infected by ingesting spores of M. grandis. Healthy adult parasites did not transmit the pathogen to larvae of the boll weevil or to progeny after stinging a diseased boll weevil larva, and diseased adult parasites did not transmit M. grandis to larvae of the boll weevil. Only 1 of 49 progeny of B. mellitor produced by diseased parents was infected.

603. ; Andrews, G.; and Bell, M. R. 1971. Field tests for control of Heliothis spp. with a nuclear polyhedrosis virus included in a boll weevil bait. J. Invertebr. Pathol. 18: 304-305.

The test design was too limited to permit evaluation of the bait for control of Heliothis spp.; however, the efficacy of the bait formulations was demonstrated. The bait induced active feeding by larvae; the virus was infective in the formulation; and many larvae became infected in the field. Also, some virus was active in the bait for at least 6 days during hot, dry, sunny weather. We feel that the bait principle should be further investigated as a means of using NPV for effective control of bollworms.

604. , and Bell, M. R. 1970. Mass production in vivo of two protozoan pathogens, Mattesia grandis and Glugea gasti, of the boll weevil, Anthonomus grandis. J. Invertebr. Pathol. 16: 84-88.

A method is described for production in vivo of large amounts of spores of Mattesia grandis and Glugea gasti, both sporozoan pathogens of the boll weevil, Anthonomus grandis. Boll weevil larvae obtained from the mass-rearing section of our laboratory, growing in artificial diet in petri dishes, are inoculated

with spores. An optimum spore dose and larval age at time of inoculation exists for each pathogen. Infected adults emerge, live a short time, and are harvested for optimum spore production. Production of the two pathogens is compared, with Glugea gasti producing more spores per insect and thus having a much lower cost. The method shows that mass production in vivo of a protozoan pathogen can be done when large numbers of the host insect can be economically grown. The pathogens were produced to support 5 years of field testing.

605. ; Bell, M. R.; and Daum, R. J. 1967. Suspension of microorganisms in a thixotropic solution. J. Invertebr. Pathol. 9: 70-77.

The rapid settling of microorganisms in suspensions introduces considerable variation in the number of spores or particles dispensed, and this difference is often great enough to prevent administration of accurate doses. Because of their thixotropic characteristics, solutions of hydroxyethyl cellulose of proper viscosity and body were used successfully to suspend spores of Mattesia grandis. Since the spores did not settle in the syringe or needle, accurate doese could be administered.

606. ; Bell, M. R.; and McReynolds, G. B. 1971. In vitro primary culture of embryonic cells from the boll weevil, Anthonomus grandis. J. Invertebr. Pathol. 17: 81-86.

When embryonic cells of boll weevils, Anthonomus grandis, were grown in primary cultures, large aggregates of cells developed the first week, pulsing actions were strong, and multiplication occurred. Then for 4-7 weeks, the tissues grew unattached, formed large aggregates, and continued to pulse and enlarge. Characteristically, the tissure developed spherical, membranous outgrowths, and cells developed peripherally and became multilayered; possibly, they possess an interior membrane. These latter growths resembled midgut cells.

607. ; Bell, M. R.; and Veal, S. D. 1966. Bacteria and fungi associated with dead boll weevils (Anthonomus grandis) in a natural population. J. Invertebr. Pathol. 8: 401-408.

An unusually large number of dead boll weevils (Anthonomus grandis) were found covered by a pinkish-white external fungus and adhering to unopened cotton bolls in an experimental cotton field in Self Creek Community, Okitbbeha County, Mississippi, in October and November 1964. A study was made of the dead weevils, and all bacteria and fungi present internally were isolated. These cultures were identified, and representatives from taxonomic groups were tested for pathogenicity. Cloaca A (Aerobacter cloacae; Enterobacter cloacae) occurred most frequently. Other bacterial isolates with similar characteristics did not fit currently recognized groups of the Enterobacteriaceae but with similar characteristics did not fit currently recognized groups of the Enterobacteriaceae but were similar in some respects to Cloaca A, Serratia, and an Intermediate group. Other genera represented were Pseudomonas, Alcaligenes, Achromobacter, Klebsiella, Lactobacillus, and Bacillus. The most frequently isolated fungi belonged to the genus Fusarium. Other fungi represented were Fusidium sp., Oedocephalum sp., Aspergillus sp., and Penicillium sp. No microorganisms tested were pathogenic. The bacteria were considered normal flora of the weevil intestinal tract, and their frequent occurrence indicated that Cloaca A and the Intermediate group were often either present in the living host or possessed special ability to grow after host death to the exclusion of other bacteria, or both. The frequent occurrence of Fusarium fungi indicated that the fungi possessed certain characteristics which permitted exclusive saprophytic growth.

608. ; Cleveland, T. C.; Daum, R. J.; and Bell, M. R. 1969. Development of the bait principle for boll weevil control. IV. Field tests with a bait containing a feeding stimulant and the sporozoans Glugea gasti and Mattesia grandis. J. Invertebr. Pathol. 13: 429-441.

Bait containing feeding stimulant and one of two protozoan pathogens (Mattesia grandis or Glugea gasti) was tested against field populations of boll weevils (Anthonomus grandis) in the fall of 1966 throughout the season in 1967. In 1966, the weevils that subsequently diapaused responded well to the bait since 60-80% had ingested the red marker dye. Also, although the quantity of the pathogen was limited, both diseases were found in the populations. In 1967, 50-70% of the weevil population present in late June and early July (overwintered weevils) ingested bait containing G. gasti, and as many as 80% were diseased. In contrast, the F_1 and ensuing reproducing generations present from mid-July through August did not respond well: only 2-19% were marked, and only 11-25% were diseased. Then after August 31, as the weevils began to enter diapause, the population again responded well, and 50-70% were marked and diseased. Also, over 60% of the weevils subsequently collected from woods trash from winter hibernation sites were marked and diseased. The treatment with the pathogens in 1967 caused 96% winter mortality of boll weevils compared with 84% in nearby untreated areas. In addition, large populations of insect predators were found in the treated area, and several gallons of one species were collected in samples of woods trash examined in April 1968.

609. ; Daum, R. J.; and Bell, M. R. 1968. Development of the bait principle for boll-weevil control. III. Field-cage tests with a feeding stimulant and the protozoan Mattesia grandis (Neogregarinida) and a microsporidian. J. Invertebr. Pathol. 12: 168-174.

When Mattesia grandis or a microsporidian were incorporated into a bait containing a feeding stimulant and a marker dye, and tested for suppression of a caged

population of the boll weevil, Anthonomus grandis, about 30-40% of the adults fed on the bait. However, rain prevented continuous and optimum coverage of the plants with the bait. Both pathogens suppressed the populations of weevils, thus producing a further demonstration of the validity of the principle of using response-eliciting materials in a bait containing a pathogen to induce disease.

610. , and Lusk, J. W. 1967. Morphogenesis of testes and ovaries in the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 60: 120-126.

The testes of Anthonomus grandis Boheman develop during larval stages from imaginal discs of primordial germ cells located in lobes of adipose tissue at about the 5th-7th abdominal segment. They are large enough to be seen through the integument during the second instar. Ovarial growth is somewhat slower, but the ovaries can be seen easily in third-instar larvae. The sex of larvae can be determined visually. Mitotic division of spermtogonia and oogonia occurs during larval development, and the male germ cells prepare for meiotic divisions during the prepupal stage. The divisions were detected immediately after pupation. The change from larval growth to metamorphosis into adult structures was thus correlated with a change in the testes from mitotic multiplication to meiotic maturation.

611. ; Scott, H. A.; and Bell, M. R. 1972. Infection of the boll weevil by Chilo iridescent virus. J. Invertebr. Pathol. 19: 285-280.

When infections with Chilo iridescent virus (CIV) were induced in larvae of boll weevils, Anthonomus grandis, by intrahemocoelic injection or by feeding, and in adults by feeding, the typical blue coloration of adipose tissue developed at 3-7 days postinfection, and mortality occurred after 3 days. The symptomatology and the pathological expressions depended on the initial infectious titer. The

virus remained viable when it was added to the feeding stimulant bait used to infect weevils with protozoan pathogens in the field, and weevils feeding on the formulation became infected when it had been exposed 1-3 days in nature.

612. , and Sikorowski, P. P. 1978. Observations of boll weevil midgut when fed natural food or on bacterially contaminated artificial diet. J. Invertebr. Pathol. 32: 64-70.

Boll weevils fed natural food had normal midgut morphology, but weevils fed bacterially contaminated artificial diet had deteriorated midguts which became progressively less functional with continued feeding on the diet. Reversal of the conditions occurred when the weevils were returned to natural food. This recovery did not take place, however, if the deterioration was too advanced. All strains of boll weevils had similar midgut responses. Cellular destruction in the midgut and loss of tissue function led to typical symptoms of starvation and desiccation during the first 10 days of adult life. Continued feeding upon contaminated food resulted in premature death. These observations show the importance of sanitation in mass-rearing procedures. It also may provide an explanation for subnormal boll weevil quality as reported by other authors who measured longevity, pheromone, and fatty acid production.

613. Mangum, C. L.; Earle, N. W.; and Newsom, L. D. 1968. Photoperiodic induction of diapause in the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 61: 1125-1128.

It was determined that diapause in adult Anthonomus grandis Boheman, could be induced by exposing eggs to 11-hr daily periods of white light and by holding subsequent stages in darkness. Adults responded to different photoperiods only if the immature stages were held in darkness. Infrared irradiation had no effect on diapause. Preliminary studies were made of the action spectrum for induction of diapause. Effects of brief interruptions in the

periods of light and darkness on diapause were also determined.

614. Matin, A. S. M. A.; Wright, J. E.; and Davich, T. B. 1980. Effect of low levels of gamma irradiation on longevity and sterility of the boll weevil. Southwest. Entomol. 5: 112-117.

Dose-effect studies with a laboratory strain of Anthonomus grandis Boheman were conducted with gamma radiation from 2 sources delivered at 2 dose rates. The 6-day-old weevils were less sensitive than the 2- or 3-day-old weevils to the effects of radiation on oviposition. The 2 dose rates of 356 rad/min and 120 rad/min from ^{60}Co and ^{137}Cs, respectively, were equal in biological effects.

615. Mauldin, J. K.; Hamner, A. L.; and Brazzel, J. R. 1966. The effect of insecticides on egg production of the boll weevil, Anthonomus grandis Boh. J. Ga. Entomol. Soc. 1: 15-19.

Periodic treatment of five generations of boll weevils with a toxaphene-DDT mixture caused a decrease in susceptibility for three generations and a subsequent leveling off. Egg production decreased gradually through the five generations of selection. Similar treatment with methyl parathion also caused a decrease in egg production, but susceptibility decreased very little through two generations of selection. Along with reducing egg production the toxaphene-DDT mixture appeared to eliminate those insects with a high reproductive potential. It would appear that the insecticides used in boll weevil control act not only as lethal agents, but also as reproduction inhibitors.

616. Maxwell, F. G. 1977. Plant resistance to cotton insects. Bull. Entomol. Soc. Am. 23: 199-203.

To illustrate the general progress being made in the field, the commodity area of cotton has been chosen, with which I have had the good fortune to be associated for nearly 12 years. The Host Plant Resistance Program developed from a few independent studies in Texas, Arkansas and North Carolina in the late 1950's and early 1960's to a major interdisciplinary, multi-state, USDA effort in 1976. Results of the program are now becoming evident with output of commercial and advance cotton breeder lines carrying resistance to a number of insect pests. Also, information presented represents not only personal research but efforts of many colleagues representing different disciplines located especially in the States of Mississippi, Texas, Louisiana, Arkansas and the Agricultural Research Service USDA, located in Texas and Mississippi.

617. . 1978. Mass rearing, sterilization, and sterile release of boll weevils. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 96-103.

Technology for mass rearing sufficient numbers of high quality boll weevils (5,000,000 per week) to conduct the first two years of the North Carolina Program exists at the Gast Boll Weevil Rearing Laboratory at Mississippi State University. This capability is recent and has resulted from well supported, intensive research following the South Mississippi Eradication Experiment. The Gast Boll Weevil Rearing Laboratory at Mississippi State University was designed and constructed to serve as a research laboratory and not as a major production facility to support a large eradication program. It does not have the design or the capacity to provide weevils for an expanded eradication effort beyond the proposed North Carolina Trial Program. Research at the Gast Boll Weevil Rearing Laboratory has shown conclusively that mass rearing of clean, competitive boll weevils, requires

sophisticated environmental controls to prevent contamination, expensive mechanical equipment for mechanization, exceptionally high quality technical and supervisory personnel, and mechanical and emergency power back-up of all essential equipment. The status of sterilization technology has increased greatly since the South Mississippi Trial Experiment but still constitutes the weakest link in the chain of technology required for successful boll weevil eradication. It is hoped that results from 1977 field trials and experiments will change this picture. Competitiveness of the sterilized weevils in the field as well as the overall efficacy of the sterile male technique with boll weevil still are not fully understood. This needs to be resolved before large area eradication is attempted. The North Carolina trial should proceed, but with the restriction that the program is not expanded beyond the second year until proper evaluation of its success and/or failure. If success is achieved, expansion should be geared directly to rearing and sterilization capability and effectiveness, as determined by research and by the availability of resources to provide for ample rearing, sterilization, and evaluation needs of the expanding program.

618. ; Hardee, D. D.; Parrott, W. L.; Jenkins, J. N.; and Lukefahr, M. J. 1969. Hampea sp., host of the boll weevil. I. Laboratory preference studies. Ann. Entomol. Soc. Am. 62: 315-318.

The attraction, feeding, and oviposition of Anthonomus grandis Boheman on the dioecious plant Hampea sp., was compared with Deltapine Smoothleaf cotton by laboratory bioassay. Plant parts and extracts of the male plant were comparable to cotton in attractiveness and stimulation of feeding, but extracts of female buds and capsules were significantly less attractive than extracts of male buds and cotton buds. A volatile repellent(s) in the extracts of the female buds and capsules probably masked the attractive material(s) present, but after storage

at 5°C these extracts became as attractive as extracts of the male plant and of cotton freshly prepared from buds stored at -90°C. Also, female buds contained significantly less feeding stimulant than male buds and cotton buds. This lesser concentration plus the volatile repellent produced a high degree of resistance to the boll weevil (nonpreference) to female buds and capsules.

619. ; Jenkins, J. N.; and Parrott, W. L. 1967. Influence of constituents of the cotton plant on feeding, oviposition, and development of the boll weevil. J. Econ. Entomol. 60: 1294-1297.

When quercetin, rutin, tannin, and gossypol were mixed in artificial adult and larval diets and fed to boll weevils, Anthonomus grandis Boheman, gossypol at 1.65 and 2.65% dry weight in the adult diet, plugs caused a statistically significant increase in feeding, and levels of 1.15-2.15% significantly increased oviposition. Feeding was also increased at all other levels though not significantly beyond the base level of 0.15%. Gossypol, incorporated into larval diets in concentrations of 2.0-3.5%, significantly reduced the weight of emerging weevils, but 3.5% was required before the production of adults was significantly reduced. Quercetin did not significantly reduce feeding or oviposition. At levels of 0.1-0.6%, it increased the weight of emerging weevils, but at all other levels weight was not significantly affected. Tannin and rutin at levels of 0-0.1% did not significantly increase or decrease feeding. Tannin reduced weevil weight significantly at 0.2, 0.6, 0.8, and 1.0% levels; rutin at levels of 0.1-1.0% did not influence the weights of adult weevils at eclosion.

620. ; Jenkins, J. N.; Parrott, W. L.; and Buford, W. T. 1969. Factors contributing to resistance and susceptibility of cotton and other hosts to the boll weevil, Anthonomus grandis. Entomol. Exp. Appl. 12: 801-810.

A large portion of the world's germ plasm of cotton has been screened at the USDA Boll Weevil Research Laboratory, State College, Mississippi during the period 1962-68 utilizing developed techniques. An oviposition suppression factor causing 25-40% reduction in number of eggs laid by the weevil has been found in Gossypium barbadense and successfully moved into upland cotton, G. hirsutum. Two years field data with frego cottons indicate that the frego character contributes a significant degree of non-preference for egg laying by the boll weevil under field conditions. The frego character is currently being combined with selected lines of G. hirsutum carrying the oviposition suppression factor. A seedling screening technique utilizing field cages and greenhouse sand flats has been shown to have significant value in screening for individual resistant plants within a commercial variety. A number of selections with 25% or more resistance to oviposition are under extensive investigation. A number of biologically active materials have been detected in the cotton plant and other hosts of the boll weevil which significantly influences feeding stimulation, feeding deterrency, repellency and attractancy of the weevil to its hosts. A highly active square abscission factor has been detected and extracted successfully from 2nd and 3rd instar larvae. The material injected into cotton squares causes 95% abscission of squares within 48-60 hours.

621. ; Lafever, H. N.; and Jenkins, J. N. 1966. Influence of the glandless genes in cotton on feeding, oviposition, and development of the boll weevil in the laboratory. J. Econ. Entomol. 59: 585-588.

In feeding tests boll weevils, Anthonomus grandis Boheman, fed significantly less on the glandless cotton lines Acala 4-42-77 GS, Atlas 182 GS, DPSL GS, Stardel GS,

Stoneville 7A GS, and Wescot GS than on the glanded current lines. In oviposition tests, the weevils laid significantly more eggs on Acala 4-42-77 GS, Wescot GS, and Coker 100A GS than on their glanded counterparts, but there was no difference in oviposition rate among the 9 other paired lines. In antibiosis tests, significantly larger weevils were reared from reconstituted lyophilized square powder diets made from 38-6 GS, Rex Smoothleaf GS, and Stardel GS than from similar diets made from the glanded parent lines. However, similar diets made from Acala 4-42-77 GS produced weevils weighing significantly less than those from glanded Acala 4-42-77. There was no significant difference in weevil developmental period between the glandless and glanded pairs studied. The results suggest that the glandless genes may not create increased susceptibility to the boll weevil, especially if care is exercised in the selection of the genetic background in which the genes will be placed.

622. Meeks, R. A., Jr.; Lloyd, E. P.; Robinson, R. C.; and Merkl, M. E. 1966. A large-scale field evaluation of boll weevil diapause control in Mississippi. J. Econ. Entomol. 59: 811-813.

In field experiments conducted in DeSoto County, Mississippi, in 1961-62, selected procedures were evaluated for effectiveness in preventing the boll weevil, Anthonomus grandis Boheman, from entering diapause. Methyl parathion spray (0.5 lb/acre) was applied at 7- to 9-day intervals in the fall of 1961, when the first boll weevils were found in diapause. A desiccant, pentachlorlphenol, was used to terminate plant growth in mid-October. Control measures reduced both fall and spring weevil populations, but these reductions were not large enough to substantially reduce the number of insecticide applications needed for boll weevil control in the next crop season. Population pressure in September, decreased effectiveness of methyl parathion in October, and an abundance of food (squares, flowers, and bolls) for surviving boll weevils in treated field contributed to the less-than-desired effectiveness

of the control program.

623. Meisch, M. V.; Nemec, S. J.; and Adkisson, P. L. 1972. Effects of temperature and photoperiod on the toxicity of azinphosmethyl and malathion to the boll weevil. J. Econ. Entomol. 65: 1021-1023.

Toxicities of ultra-low-volume sprays of azinphosmethyl and malathion to Anthonomus grandis Boheman were evaluated under various photoperiods and temperatures. Weevils were exposed to insecticide-treated plants and held in 6 test environments: 80°F in continuous light (LL); 80°F and a photoperiod of LD 10:14 (i.e., 10 hours of light and 14 hours of dark per 24-hour cycle); 62-80°F truncated temperature change in LD 10:14; 62-80°F gradual temperature change in LD 10:14; 62°F in LL; and 62°F in LD 10:14. Toxicity produced by both insecticides showed a positive temperature coefficient as greater weevil mortalities occurred at higher temperatures than at lower. Azinphosmethyl killed greater percentages of weevils than malathion in the warmer temperature regimens of 80°F in LL, 80°F in LD 10:14, and 62-80°F truncated temperature change in LD 10:14. Malathion was more toxic to weevils than azinphosmethyl in the cooler temperature regimens of 62°F to 80°F in LD 10:14 gradual temperature change. Whereas temperature exerted an obvious influence on the toxicities of malathion and azinphosmethyl to boll weevils, no apparent effects were due to photoperiodism.

624. Merkl, M. E. 1976. Postexperiment developments of the Pilot Boll Weevil Eradication Experiment. In Boll Weevil Suppression, Management, and Elimination Technology. Proc. of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 119-121.

Two potential problems associated with the sterile-male release were: (1) Release of about 2% females from errors in sexing, and (2) release of insects that were not totally sterile. Field 43 (3 acres, zone I, unit 1), located about 2 mi west of Angie, La., showed the results of the interaction of these two problems. On

August 23, two in-field traps were installed in field 43 and baited with grandlure. On August 24, one ebony male and one ebony female were collected in the traps. On August 28, eight egg-punctured squares were collected from the field. These squares yielded 7 larvae (3 first, 3 second, and 1 third instar) and one good egg. In-field traps on the same date contained one ebony male, one ebony female, one native male and three native females. The same traps contained two ebony males and two ebony females on August 29. During the first 3 weeks in September, 64 ebony, 150 bronze and 6 native weevils were captured in 2 traps. On September 19, 25 weevils were collected by shagging 100 ft. of row. There were 6 ebony, 17 bronze, and 2 native weevils in this collection. Another shagging collection of 74 weevils had 64 ebony and 10 bronze weevils. From August 24 until January 23, a total of 1,295 weevils were collected from this field. Ten native weevils were captured on January 23. This field is unique since it was the only field in zone I found to develop a general field infestation during August. On December 10-13, 1973, woods-trash samples were collected from zones I, II, and III, and an outside sample was also collected along the Natchez Trace for comparison. Each sample consisted of 2 yd of suitable woods trash taken from areas adjacent to cottonfields. Varying numbers of samples were taken from each field. These records show an average of 48.4 weevils per acre in woods trash in zone I compared with 1,452 per acre in zone II, 15,488 per acre in zone III, and 7,018 per acre outside the area.

625. . 1978. Grandlure for boll weevils: test of new formulations in Mississippi. J. Ga. Entomol. Soc. 13: 273-276.

Sixteen mg of grandlure (a mixture of (+)-cis-2-isopropenyl-1-methylcyclobutane-ethanol, (Z)-3. 3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol, (Z)-3, 3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde, and (E)-3, 3-dimethyl-$\Delta^{1,\alpha}$-cyclohexane-acetaldehyde in approximately equal proportions) formulated in laminated plastic attracted Anthonomus grandis Boheman for 4 weeks when the dispenser was exposed in commercial plastic

traps. A similar formulation containing 40 mg grandlure was effective for 8 weeks when it was exposed in Leggett traps. Unbaited Leggett traps caught some weevils; unbaited plastic traps did not.

626. ; Cross, W. H.; and Johnson, W. L. 1978. Boll weevil: detection and monitoring of small populations with in-field traps. J. Econ. Entomol. 71: 29-30.

In-field traps were superior to other techniques for detecting very low populations of Anthonomus grandis Boheman in cotton fields. Five, 10, 15, 20, and 25 in-field traps/ha were compared in an isolated cotton field in Arkansas. Only one punctured square and no live weevils were found in hand examinations during the experiment. No weevils or punctured squares were found with an insect collecting machine. A total of 25 overwintered weevils and 71 field generation weevils was captured with in-field traps from May 26-Sept. 7. Twenty-five traps/ha captured the majority of weevils caught during the test.

627. ; Lane, H. C.; and McCoy, J. R. 1980. Narrow row cotton in Mississippi: effect on insects and yield. J. Ga. Entomol. Soc. 15: 109-114.

Infestations of cotton pests were more severe on cotton planted early in the season in narrowly spaced rows than in cotton planted at normal density, but were not more severe when the cotton was planted in mid- or late-season. However, in some tests yields from cotton planted densely were slightly greater than, and in other tests similar to, yields from cotton planted at normal density.

628. , and McCoy, J. R. 1978. Boll weevils: seasonal response over five years to pheromone baited traps. J. Econ. Entomol. 71: 730-731.

In a 5-yr study in the hill area of Mississippi, boll weevils, Anthonomus grandis grandis Boheman, were captured every month of each year, except March 1974. The largest numbers were captured in Oct. and the smallest numbers in Mar. Totals

captured from 1971 through 1975 were 8959, 3399, 2058, 1213, and 715, respectively. Averages captured per trap per month ranged from 0-164.3.

629. Minyard, J. P.; Hardee, D. D.; Gueldner, R. C.; Thompson, A. C.; Wiygul, G.; and Hedin, P. A. 1969. Constituents of the cotton bud compounds attractive to the boll weevil. J. Agric. Food Chem. 17: 1093-1097.

Essential oil from buds of the cotton plant (Gossypium hirsutum L. CV Deltapine Smoothleaf) was fractionated by several procedures. Mixtures and single compounds thus obtained were bioassayed for plant attractancy to the boll weevil, Anthonomus grandis Boheman. Compounds present in cotton and active as components of the plant attractant complex are (-)-α-pinene, (-)-limonene, (-)-β-caryophyllene, (+)-β-bisabolol (a sesquiterpene alcohol reported only in cotton thus, far), caryophyllene oxide, and two as yet unidentified sesquiterpenoids. The boll weevil-cotton plant attractant complex thus appears to be a mixture of many compounds. An aqueous mixture of 10. 3, 100, 100, and 30 p.p.b., respectively, of commercial (+)-α-penene and (+)-limonene, cotton bud oil (-)-β-caryophyllene and (+)-β-bisabolol, and synthetic caryophyllene oxide from cotton (-)-β-caryophyllene, is 124% as attractant in laboratory assays as the best available attractant mixture from cotton buds. This synthetic mixture remains highly attractive to boll weevils at concentrations 30-fold higher and 10-fold lower.

630. Mistric, W. J., Jr. 1968. Comparative effect of the boll weevil on the productivity of Coker 100 W and Deltapine 15 cotton in North Carolina. J. Econ. Entomol. 61: 284-285.

Fruiting and yield characteristics of semideterminate Coker 100 W and nondeterminate Deltapine 15 cotton were compared under conditions of (1) heavy boll weevil, Anthonomus grandis Boheman, infestation and (2) virtually on infestation. Varietal differences in the trends in fruiting and yield were similar

in the presence and absence of weevils. Under each condition, Deltapine 15 produced a significantly lower yield than Coker 100 W. The decreased yield of Deltapine 15 were due to greater square and boll abscission and the production of smaller bolls, rather than to greater susceptibility of this variety to weevils. Deltapine 15 fruited as early as Coker 100 W, and its nondeterminate growth was not expressed. Hence, the boll weevil did not limit the productivity of Deltapine 15 any more than it limited the productivity of Coker 100 W.

631. . 1968. Effects of nitrogen fertilization on cotton under boll weevil attack in North Carolina. J. Econ. Entomol. 61: 282-283.

Square, bloom, and boll production of cotton increased as nitrogen fertilization was increased from 35 to 105 lb per acre. More boll weevils, Anthonomus grandis Boheman, were attracted to the more heavily fertilized cotton, and greater numbers of squares and bolls were damaged by weevils. However, the percentage of damaged fruits did not vary significantly. Consequently, both yield and weevil damage increased as nitrogen fertilization was increased.

632. , and Covington, B. M. 1968. Effects of square removal on cotton production with reference to boll weevil damage. J. Econ. Entomol. 61: 1060-1067.

Effects of increasing, constant, and fluctuating patterns of square removal (averaging 45% for 8 weeks) on fruiting characteristics, early date, and yield of Coker 100 W cotton in North Carolina were investigated during 1957-59 in an area protected from boll weevils, Anthonomus grandis Boheman. Plants compensated for each pattern of square removal by increasing square production, the percentage of bolls, set, and the average weight of bolls. However, the extent to which each of these plant responses contributed to the total compensation varied with the patterns of square removal. The increasing pattern of square removal increased square produc-

tion the least, the constant pattern increased average boll weight the least, and the fluctuating pattern increased the percentage of bolls set the least. Effects of the different patterns of square removal on yield were not significant, but effects on early date of production and harvest were significant and of practical importance. The fluctuating pattern of square removal delayed total production 10 days and total harvest 15 days. Both production and harvest were delayed an additional 2 weeks by the constant pattern of square removal and 3 weeks by the increasing pattern. The fluctuating pattern of square removal more nearly approximates weevil infestations in North Carolina, and it is potentially less detrimental to cotton production than the constant and increasing patterns. The effect of boll weevil square infestation on the yield of treated cotton was similar to the effect of square removal on the yield of protected cotton, that is, up to 45% (8-week average) square infestation or removal had no significant effect on yield. At about this level of square infestation, the yield of untreated cotton was reduced 50-60%, principally because of boll damage and boll abscission caused by weevil attack. Thus, within this level of square infestation, protection of the yield was mostly a matter of protecting bolls. Three treatments schedules are described which protected the yeild at square-infestation levels, ranging from about 10 to 45%.

633. , and Covington, B. M. 1968. A preventive boll weevil control program applied to a ten-square-mile area within an untreated county. J. Econ. Entomol. 61: 186-190.

A preventive control program against the boll weevil, Anthonmus grandis Boheman, was applied to a 10-square-mile area within untreated Roberson County, North Carolina, in 1960. The treatment schedule consisted of 4 early-season insecticide applications beginning at the 8-leaf stage of cotton growth plus late-season applications beginning the last week of July and continuing to the end of squaring.

Approximately 95% control of overwintered weevils was obtained with the early-season applications, resulting in approximately 88% control of F_1 boll weevils. When F_2 boll weevils emerged, control declined steadily to 16% as migrants entered the treated fields and depressed yields. The increase in boll weevils from the overwintered to the peak late season population was 21-fold in untreated fields and 856-fold in treated fields, indicating the magnitude of migration. Nevertheless, 6 insecticide applications increased the average yield of seed cotton 426 lb/acre. More than 1 bale/acre was produced in 29% of the treated fields and in none of the untreated fields.

634. , and Covington, B. M. 1969. End of squaring as an economic indicator of approximate time to end insecticidal treatments for boll weevil control. J. Econ. Entomol. 62: 35-36.

Under various field conditions in North Carolina, cotton planted in mid-April started squaring in mid-June, stopped squaring in mid-August or earlier, and did not produce bolls which failed to open prior to the first fall freeze. Square infestation by Anthonomus grandis Boheman was reduced and the yield of cotton was economically increased by insecticidal treatments applied at approximately 5-day intervals from the time the square infestation in July reached 10% until the end of squaring. After the end of squaring, additional treatments applied at approximately 5-day intervals did not reduce the adult boll weevil population or increase the yield of cotton. Hence, from the economic standpoint of cotton production, the end of squaring (less than 1 square per linear ft of row) indicated the approximate time to end insecticidal treatments for boll weevil control.

635. ; Covington, B. M.; and Smith, F. D. 1970. Effects of methyl parathion, DDT, and toxaphene on the boll weevil, bollworm, and cotton plant in North Carolina. J. Econ. Entomol. 63: 596-599.

Toxaphene + DDT, methyl parathion + DDT, and toxaphene + DDT + methyl parathion

sprays applied early and late in the cotton season provided adequate control of the boll weevil, Anthonomus grandis Boheman, and the bollworm, Heliothis zea (Boddie), during 1961-63. Differences in effectiveness of these treatments against these insects were not significant. Also, no significant differences in total square or boll production, plant height at harvest, or total yield were found among these treatments. Treatments of methyl parathion + DDT and toxaphene + DDT + methyl parathion delayed squaring about 5-10 days, and this delay in squaring, resulted in a corresponding delay in maturity. Thus, the reproductive physiology of cotton was affected slightly by methyl parathion.

636. , and Mitchell, E. R. 1966. Attractiveness of isolated groups of cotton plants to migrating boll weevils. J. Econ. Entomol. 59: 39-41.

Migrating boll weevils, Anthonomus grandis Boheman, were attracted in considerable numbers to isolated groups of caged and uncaged fruiting cotton plants. Few to no weevils were attracted to more mature cotton plants. Weevils were able to differentiate between fruiting and immature plants without having to alight on the plants. The distance from which the weevils were attracted was in excess of 1 foot. The field-cage technique appeared to offer opportunities for research on the comparative attractiveness of various plant materials and the distances from which weevils are attracted. This technique may be useful also in determining the time and extent of weevil migration.

637. , and Mitchell, E. R. 1968. Preventive boll weevil control program applied to a ten-square-mile area within a treated county. J. Econ. Entomol. 61: 179-186.

Three insecticides applied at 2 dosages and 2 application intervals (3 X 2 X 2 factorial) were used in a preventive boll weevil, Anthonomus grandis Boheman, control program consisting of 3 or 4 early-season applications beginning at the 8-leaf stage of cotton growth plus late-season applications beginning the last

week of July and continuing to the end of squaring. No economic benefits were derived by exceeding minimum recommended dosages or reducing maximum recommended intervals. Statistically significant but relatively small practical differences in boll weevil control, square production, and yield were noted among treatments of azinphosmethyl-DDT, carbaryl, and toxaphene-DDT. In comparison with nearby untreated cotton, the preventive treatments reduced the boll weevil population 81% in early and mid-season and 77% in late season. The treatments increased the yield of seed cotton 1378 lb/acre, averting a 42% reduction in boll set and 41% boll damage. In comparison with a treatment schedule based upon 10% square infestation, the preventive schedule (1) reduced the late season boll weevil population 88%, (2) shortened the fruiting period about 10 days, (3) was easier to follow, and (4) required only about half as many applications. Similar yields were obtained with the 2 schedules.

638. Mitchell, E. B. 1978. Pheromone trapping as an index for initiating control of boll weevils. Proc. 1978 Beltwide Cotton Prod. Res. Conf., pp. 115-116.

Pheromone traps have been tested primarily for suppressing or controlling a weevil population and for survey and detection. They have proved to provide the most effective available method of detecting light weevil infiltration; however, their value for suppression and control is not clear at the present time.

639. , and Hardee, D. D. 1974. In-field traps: a new concept in survey and suppression of low populations of boll weevils. J. Econ. Entomol. 67: 506-508.

Grandlure-baited traps placed in the field captured boll weevils, Anthonomus grandis Boheman, when manual surveys failed to detect signs of infestations. An aggregating response was obtained from both sexes in early and late season

as in previous trap studies, but significant numbers of boll weevils, primarily females, were captured in mid-season, thus indicating a true sex pheromone at this time of year. Previous trap studies failed to obtain this mid-season response. In-field traps provide a new and promising approach to survey and monitoring efforts, to evaluate an elimination program, and to the actual management and suppression of the boll weevil.

640. , and Hardee, D. D. 1974. Seasonal determination of sex ratios and condition of diapause of boll weevils in traps and in the field. Environ. Entomol. 3: 386-388.

Boll weevils, Anthonomus grandis Boheman, captured in traps were not always representative of field populations with respect to sex ratio and status of diapause. From June to mid-winter, the ratios of captured females to males are higher than they are in field populations. In the fall, the percentage of boll weevils in the field that are in diapause is higher than the percentage among those captured in traps.

641. , and Hardee, D. D. 1976. Boll weevils: attractancy to pheromone in relation to distance .. wind direction. J. Ga. Entomol. Soc. 11: 113-117.

The long range movement of Anthonomus grandis Boheman to primarily with the wind. They probably are not able to detect an attractant further than 500-600 ft and move at random with the wind until they come within this distance of the attractant source.

642. ; Hardee, D. D.; Cross, W. H.; Huddleston, P. M.; and Mitchell, H. C. 1972. Influence of rainfall, sex ratio, and physiological condition of boll weevils on their response to pheromone traps. Environ. Entomol. 1: 438-440.

Tests with traps baited with male Anthonomus grandis Boheman indicated that early-spring temperature influenced emergence of overwintered weevils but

that rainfall had more influence as temperatures increased. Since higher percentages of males than females were captured early in the spring and the reverse became true later, the pheromone may serve initially as an aggregating factor and then subsequently as a true sex attractant. Most weevils emerged in the spring with little fat reserve, but the variation in the amount of fat reserve among individuals may account for the emergence of boll weevils over such an extended period.

643. ; Hardee, D. D.; and Wilson, N. M. 1975. Male boll weevils: studies relating to attractancy. J. Econ. Entomol. 68: 150-152.

The attractiveness of male Anthonomus grandis Boheman was closely related to the passage of fecal material. The frass was more attractive than the male, and the rate of attractancy of a starved weevil placed on food increased at approximately the same rate as the increase in food passage.

644. ; Haynes, J. W.; Huddleston, P. M.; and Hardee, D. D. 1975. Feasibility of sterilizing emerging overwintered boll weevils with bait stations. J. Econ. Entomol. 68: 610-612.

Overwintered Anthonomus grandis Boheman can be sterilized and egg laying can be greatly reduced in the laboratory by feeding them a diet containing busulfan (1,4-butanediol dimethanesulfonate). A feeding table designed to attract weevils as they emerged from hibernation quarters attracted a small percentage of the total overwintered weevils that were in the field on July 1.

645. ; Hopkins, A. R.; Walker, J. T.; and James, W. 1966. Winter mortality of boll weevils in cotton bolls in South Carolina. J. Econ. Entomol. 59: 1027-1028.

Boll weevils lived longer in bolls held in the insectary than in any of the other treatments. However, none of the estimated 29,754 boll weevils inside the bolls in the insectary and in the hibernation cages survived the winter. A total

of 395 weevils emerged at irregular intervals from the bolls held in the insectary from November 30, 1964, through February 28, 1965. These and 1424 additional weevils which emerged from extra bolls collected at the same time as those used in the various treatments were placed in hibernation material without having fed after emerging. Only 1 of these 1819 unfed adults survived the winter. Examination of the 2 cracked bolls in which the 2 adult weevils were found on April 15 did not reveal weevils developmental cells. This finding indicated that weevils present inside the bolls had not developed there. Results showed that although boll weevils in this area may live either in the immature or adult stage in cells in bolls for several weeks during the winter, they have little chance of surviving under these conditions until cotton plants again become available in the spring. Moreover, weevils that emerge from bolls in the winter after all sources of food have been eliminated have very little chance of surviving.

646. ; Huddleston, P. M.; and McKibben, G. H. 1978. Boll weevil traps: influence of size on capture efficiency. J. Ga. Entomol. Soc. 13: 222-226.

Four different size traps of similar design were compared. One that has a fluorescent yellow base ca. 1 liter in size compared favorably with larger traps for detection and removal of boll weevils, Anthonomus grandis Boheman.

647. ; Huddleston, P. M.; and Wilson, N. M. 1977. Influence of mating sterile male boll weevils to overwintered females. J. Econ. Entomol. 70: 76-77.

When overwintered females of Anthonomus grandis Boheman, collected from areas with low and high populations of weevils, were crossed with sterile males, egg hatch was reduced from ca. 90 to 10%. Percentage hatch was about the same for females from the 2 areas.

648. ; Huddleston, P. M.; Wilson, N. M.; and Hardee, D. D. 1973. Boll weevils: relationship between time of entry into diapause and time of emergence from overwintering. J. Econ. Entomol. 66: 1230-1231.

There was a correlation between the time of entrance into hibernation and the time of emergence the following spring and summer. The late-emerging weevils apparently went into diapause early, and the early emerging weevils were those that were in the fields late the previous fall.

649. ; Lloyd, E. P.; Hardee, D. D.; Cross, W. H.; and Davich, T. B. 1976. In-field traps and insecticides for suppression and elimination of populations of boll weevils. J. Econ. Entomol. 69: 83-88.

Grandlure-baited in-field traps used at the rate of 10/acre captured 76% of a population of overwintered Anthonomus grandis Boheman estimated to number ca. 25/acre that emerged between the time cotton was planted and the time the plants produced pinhead squares. A combination of in-field traps and insecticides captured or killed 100% of the emerging overwintered weevils during the 23 days between the pinhead square stage of plant growth (June 13) and July 6. The traps alone captured ca. 96% of a late emerging population of ca. 1 boll weevil/acre during July 6-31. The problem of clumping of F_1 and F_2 progeny proved to be an important factor in the efficiency of the traps.

650. ; Lloyd, E. P.; Wood, R. H.; and Johnson, W. L. 1977. Evaluation of high density trapping alone and in combination with insecticides against the boll weevil. J. Ga. Entomol. Soc. 12: 141-145.

In-field traps baited with grandlure (the synthetic attractant of the boll weevil) were tested at the rate of 20/acre between the time cotton was planted and the time plants produced pinhead squares. These traps captured ca. 79% of the emerging population of overwintered Anthonomus grandis Boheman determined to number ca. five/acre. A combination of the 20 in-field traps/

acre plus nine treatments with azinphosmethyl applied at 3-, to 6-day intervals during a 5-week period beginning July 29 did not eliminate an isolated boll weevil population of reproducing weevils.

651. ; McGovern, W. L.; and Huddleston, P. M. 1979. Influence of field applications of diflubenzuron on longevity, fertility, and attractiveness of released irradiated boll weevils. J. Ga. Entomol. Soc. 14: 251-254.

The attractiveness and longevity of released males of Anthonomus grandis grandis Boheman, irradiated as pupae, were not affected by the exposure of foliar applications of diflubenzuron. However, egg hatch from normal virgin females paired with these males was greatly reduced.

652. ; McGovern, W. L.; and Wilson, N. M. 1977. Boll weevils: sterility induced by ^{32}P tagging. J. Econ. Entomol. 70: 393-394.

Beta particles arising from ^{32}P in paint placed on the wing cover of females of Anthonomus grandis Boheman reduced longevity, egg production, and egg hatch. Egg hatch also was reduced in eggs collected from females mated with ^{32}P-tagged males. Although ^{32}P at the dosage used may be satisfactory for tagging boll weevils for movement studies, it is not satisfactory as a label for weevils that are expected to reproduce normally.

653. ; Merkl, M. E.; Wright, J. E.; Davich, T. B.; and Heiser, R. F. 1980. Sterility of boll weevils in the field following treatment with diflubenzuron and gamma irradiation. J. Econ. Entomol. 73: 824-826.

Over 600,000 mixed sex sterile Anthonomus grandis grandis Boheman that had been sterilized by feeding them diflubenzuron treated diet for 6 days and then irradiating them were released in 2.4 ha of cotton in south Florida. Results showed that a boll weevil population was not established in the field which indicated that all of the insects were sterilized.

654. , and Taft, H. M. 1966. Host-plant selection by migrating boll weevils. J. Econ. Entomol. 59: 390-392.

Field experiments were conducted at Florence, S.C., in 1963 and 1964 to study the roles of odor and color in selection of host plants by the boll weevil, Anthonomus grandis Boheman. Periodic removal of all or part of the fruiting forms from cotton plants did not reduce their attractiveness to this insect. Moreover, boll weevils were attracted to fruiting cotton plants in significantly larger numbers than to cocklebur plants of similar size and color, or to green- or red- painted plastic forms, indicating that under the conditions of the tests the primary attractant of cotton plants to the insect is odor.

655. , and Taft, H. M. 1966. Starvation method for obtaining diapausing boll weevils able to survive the winter in hibernation. J. Econ. Entomol. 59: 55-57.

Fall field-collected boll weevils, Anthonomus grandis Boheman, were separated into diapausing and nondiapausing groups by withholding food for 1 to 3 weeks. All nondiapausing weevils died during the starvation period. Records indicated that weevils may not require large amounts of fat for winter survival.

656. Mitchell, H. C. 1971. Behavior study of overwintered boll weevils employing radioactive tags. Diss. Abstr. Int. B. 32: 2212B.

Boll weevils, Anthonomus grandis Boheman, were successfully tagged using Zn^{65} in the form of zinc oxide placed in butyrate dope and painted on the elytra of the insect. A small syringe placed on an electric micro-applicator located behind lead bricks was used in tagging the individual weevils at the tip of a no. 22 needle. Weevils which have approximately 100 uc of the isotope applied can be detected 76 to 91 cm away by using a solid 1 in. x 1 in. NaI scintillation probe.

657. , and Cross, W. H. 1969. Oviposition by the boll weevil in the field. J. Econ. Entomol. 62: 604-605.

Oviposition by Anthonomus grandis Boheman was observed in detail in the field. Average time from intial mating to 1st oviposition was 21 minutes, but the oviposition time for overwintered females was longer than for females of the subsequent generation. The process of puncturing the square and depositing the egg required an average of 6 1/4 minutes for overwintered females and 4 1/2 minutes for females of the subsequent generation. Females deposited almost 1 egg per hour at a fairly smooth pace throughout the day starting at about 0800 hr. Apparent peaks were noted between 0900 and 1000 hr, and between 1200 and 1300 hr. The number of eggs deposited per hour was also somewhat reduced in the overwintered generation.

658. , and Cross, W. H. 1971. Mating of boll weevils in the field. J. Econ. Entomol. 64: 73-74.

Mating habits of the boll weevil, Anthonomus grandis Boheman, have been investigated considerably since this insect entered the United States. Thus, early workers reported that the female weevil required only 1 mating to produce fertile eggs throughout its lifetime, but they did not discount the possibility that multiple matings occurred in the field. Also, Hunter and Pierce reported that the average duration of copulation was ca. 30 min. Mayer and Brazzel reported that 1 mating time ranged from 15 to 30 min. In contrast, Bartlett found that the average mating time for a wild strain of boll weevils was 54±3.5 min for the 1st matings; the average duration of subsequent matings was the same if the females mated every 4 days. Current interest in the sterile-male technique of controlling insect pests has generated new interest in the mating habits and utilization of sperm by female insects. These mechanisms were therefore investigated in the boll weevil in laboratory studies. The present paper reports the results obtained when the

mating behavior of boll weevils was observed continuously in a field where the females were allowed to move freely to seek males for mating.

659. ; Cross, W. H.; McGovern, W. L.; and Dawson, E. M. 1973. Behavior of the boll weevil on frego bract cotton. J. Econ. Entomol. 66: 667-680.

In a detailed study of the behavior of Anthonomus grandis Boheman in frego bract and 'Deltapine Smooth Leaf' (DPSL) cotton, 2.5 times as many weevils were trapped in or around the DPSL as around the frego bract cotton. Also, boll weevils moved smoewhat more in frego than in DPSL cotton, since about 1/2 as many introduced weevils were recovered in frego as in DPSL. In DPSL, 64% of the weevils recovered were found in squares, only 20% were recovered in squares on frego cotton. Both overwintered, and current-generation female weevils deposited about twice as many eggs per hour in the DPSL as in the frego bract cotton.

660. ; McGovern, W. L.; Cross, W. H.; and Mitlin, N. 1973. Boll weevils: tagging for hibernation and field studies. J. Econ. Entomol. 66: 563-564.

The purpose of the study was to develop a tagging method using a radioisotope that would remain on or in the weevil in sufficient quantities that they could be found and that would not have an adverse effect on the insect. The material ^{65}Zn was ultimately selected as the test isotope because of its availability and its half life was long enough that the weevils could be detected for months after tagging. Later, ^{32}P was used in a short-time field study.

661. Mitlin, N., and Hedin, P. A. 1974. Biosynthesis of grandlure, the pheromone of the boll weevil, Anthonomus grandis, from acetate, mevalonate, and glucose. J. Insect Physiol. 20: 1825-1831.

The steam-distilled feces of adult male boll weevils, Anthonomus grandis, that had been injected with acetate-1^{14}C, acetate-2^{14}C, mevalonic acid-2^{14}C, or glucose^{14}C(U) showed by column and gas chromatography that approximately 0.02

percent of the administered radioactivity was incorporated into the volatile fraction. Also, 4 components of the pheromone comprised 57 to 80 percent of the radioactivity of the volatiles but only 39 percent of the total content of volatiles. Thus, evidence was obtained for de novo synthesis of the components. Although the boll weevil is essentially an obligate insect of cotton, this insect does not appear to require an specific component in cotton for biosynthesis of the pheromone.

662. ; Lusk, G. J.; and Wiygul, G. 1967. An electrophoretic study of the changes in proteins in the haemolymph during the life cycle of the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 60: 1155-1158.

In electrophoretic study of the proteins in the haemolymph of the boll weevil, Anthonomus grandis Boheman, throughout its life cycle, 14 proteins were found, including one that was unique to the larval stage and one that was unique to the pupal stage. Also, several glycoproteins and lipoproteins were found. Some proteins were common to all stages of the developing insect. However, no definitive correlation could be made between proteins in the egg and in the haemolymph.

663. ; Mauldin, J. K.; and Hedin, P. A. 1966. Free and protein-bound amino acids in the tissues of the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae), during metamorphosis. Comp. Biochem. Physiol. 19: 35-43.

(1) The free and protein-bound amino acids in the pupal tissues during metamorphosis in the boll weevil, Anthonomus grandis Boheman, were identified and their amounts estimated. (2) Twenty-one amino acids plus ammonia were detected and identified in the extract of free amino acid; hydrolysis revealed 3 more. (3) In the tissue protein 22 amino acids were identified. (4) The total amounts of

the free amino acids rose from a low point at the prepupal stage, receded at pupal stage 2 and rose to a higher level just before eclosion. (5) The protein-bound acids remained constant, showing little fluctuation; the individual amino aicds followed a similar course.

664. ; Reily, V. L.; and Gast, R. T. 1966. Color preference in the feeding behavior of the boll weevil. J. Econ. Entomol. 59: 598-599.

The influence of color on the feeding of the boll weevil, Anthonomus grandis Boheman, was determined by the response of the weevil to feeding plugs, with and without the addition of a feeding stimulant, dyed red, orange, yellow, green, blue, or violet, and to undyed plugs. The boll weevils preferred the dyed to the undyed plugs, but discriminated but little among the dyed plugs.

665. , and Wiygul, G. 1969. Incorporation and matabolism of ^{14}C-labeled tryptophan-3 in the boll weevil, Anthonomus grandis Boheman. Comp. Biochem. Physiol. 30: 375-381.

1. When ^{14}C-labeled tryptophan-3 was injected into boll weevils, Anthonomus grandis Boheman, the amount of radioactivity in the free amino acids pool dropped quickly at first and then more gradually until the twelfth hr post injection. Incorporation into the lipoprotein and protein fractions also peaked at 12 hr but with the nucleic acids, incorporation was gradual. 2. All RNA bases were labeled early (4 hr) but complete labeling of the DNA bases did not occur until 18 hr postinjection. The amount of labeling varied with time. 3. The lipid fraction was labeled, but activity was too low to determine the extent of incorporation into individual fatty acids. 4. Both essential and non-essential amino acids were labeled.

666. , and Wiygul, G. 1970. Effect of γ-irradiation on utilization of glycine carbons in biosynthesis of RNA and amino acids in the boll weevil. J. Insect Physiol. 16: 2271-2279.

Irradiation of boll weevils, Anthonomus grandis, caused a significant decrease in the amounts of valine, isoleucine, and histidine and an increase in the amount of cystine in the free amino acids but had no quantitative effect on the protein-bound amino acids. Also, in 4 hr it did not affect the incorporation of glycine-1-^{14}C or glycine-2-^{14}C into RNA or the synthesis of the ribonucleic acids. All the carboxyl-labeled carbon of glycine was incorporated into the same positions of both serine and glycine in both the free amino acid and the protein fractions, but some randomization occurred with the α carbon in both irradiated and normal insects. The α carbon of glycine contributed little to the formation of CO_2; the carboxyl carbon contributed materially.

667. , and Wiygul, G. 1971. Synthesis of nucleic acid and protein in the boll weevil fed with busulfan. Ann. Entomol. Soc. Am. 64: 822-824.

Busulfan (Myleran® (1,4-butanediol dimethanesulfonate)) fed to Anthonomus grandis Boheman (Coleoptera: Curculionidae) inhibited the biosynthesis of DNA and of protein but not the biosynthesis of RNA. Treatment with busulfan did not affect the excretion of $^{14}CO_2$ from weevils injected with uridine-2^{14}C or thymidine-2^{14}C, but it did appear to affect the rate of excretion of $^{14}CO_2$ from weevils injected with lysine-^{14}C (U). Sterility in the boll weevil therefore results in part from this inhibition of biosynthesis.

668. , and Wiygul, G. 1972. Contribution of pyrimidines to the biosynthesis of fecal uric acid in normal and busulfan-treated boll weevils. Ann. Entomol. Soc. Am. 65: 612-613.

Fecal uric acid from Anthonomus grandis Boheman (Coleoptera: Curculionidae) injected with thymidine-2-^{14}C and uridine-2-^{14}C was radioactive; the guanine present in the feces was not. In normal weevils treated with thymidine, the

greatest amount of activity was in the carbon 6 fraction; in similar weevils treated with uridine, the greatest amount was in the carbon 2 and 8 fractions. The pattern of labeling in normal weevils treated with thymidine was changed by force-feeding the weevils with busulfan.

669. , and Wiygul, G. 1973. Uric acid in nucleic and amino acid synthesis in the boll weevil, Anthonomus grandis. J. Insect Physiol. 19: 1569-1574.

When uric acid-2-^{14}C was injected into the boll weevil, Anthonomus grandis, it was metabolized to RNA, DNA, amino acid, and $^{14}CO_2$ at the end of 2 hr. The free amino acids, lipoamino acids, and protein amino acids were all labelled with the free amino acids showing the highest specific activity. Incorporation in DNA was slight, but it was extensive in RNA' cytidylic acid showed the greatest amount of incorporation.

670. , and Wiygul, G. 1976. A comparison of certain aspects of nitrogen metabolism in non-diapausing and diapausing boll weevils, Anthonomus grandis. Insect Biochem. 6: 207-209.

Both DNA and RNA were lower in males and females of a diapausing strain of boll weevils, Anthonomus grandis 10 to 15 days after emergence than in newly-emerged insects of the same strain. Protein content remained relatively constant in the strain of diapausing weevils, but increased substantially in the 10 to 15-day boll weevils of a non-diapausing strain; the relationship of lipoprotein to protein generally remained about the same in both strains for weevils of different ages of the same strain. Since the RNA-DNA ratios differed materially only in the 10 to 15-day diapausing males (2.2), it might be used as a corroborative indicator of diapause. The hypothesis that the boll weevils stores nitrogen as uric acid during diapause was disproven; rather the amount of stored uric acid diminished at the onset of diapause.

671. ; Wiygul, G.; and Haynes, J. W. 1977. Inhibition of DNA synthesis in boll weevils (Anthonomus grandis Boheman) sterilized by Dimilin. Pestic. Biochem. Physiol. 7: 559-563.

When boll weevils, Anthonomus grandis Boheman, were treated with Dimilin (N-(4-chlorophenyl)-N'-(2, 6-difluorobenzoyl)urea), the biosynthesis of deoxyribonucleic acid was inhibited in the female, but neither ribonucleic acid nor protein synthesis was affected. Treated males showed a difference in effect in lipoprotein synthesis, whereas no significant difference was demonstrated with females. Testicular growth was inhibited in some of the males. Diminishment of sexual function may therefore result in part from inhibition of biosynthesis of DNA by Dimilin.

672. ; Wiygul, G.; and Lusk, G. J. 1968. Incorporation of lysine-6-C^{14} into the protein of the adult boll weevil, Anthonomus grandis. J. Insect Physiol. 14: 1277-1283.

The incorporation of lysine-6-C^{14} was observed at regular intervals for 24 hr after it was injected into the haemocoele of the boll weevil, Anthonomus grandis Boheman. As the concentration of amino acid diminished in the free amino acid pool, it rose in the protein fraction. However, the concentration in the pool tended to reach equilibrium at a relatively high level after 4 hr, whereas that in the protein fraction levelled off at about 8 hr. The lipoprotein fraction was labelled quickly, within the first hour, and lost its activity as quickly. Probably at least part of the labelled lysine was incorporated into the lipoprotein fraction before it was incorporated into the protein fraction.

673. ; Wiygul, G.; and Mauldin, J. K. 1968. The free amino acids in the haemolymph of the maturing adult boll weevil, Anthonomus grandis Boheman. Comp. Biochem. Physiol. 25: 139-148.

1. The free and hydrolyzed free amino acids in the haemolymph of the boll weevil, Anthonomus grandis Boheman, were identified, and the amounts present during the first 5 days of adulthood were estaimated. 2. In all, thirty

ninhydrin-positive compounds were found, and of these, twenty-six were identified and, in most cases, quantitated. 3. Differences were found in both the titer of the total amino acids on a daily basis and in the amounts of individual amino acids, particularly tyrosine. 4. Total nitrogen levels varied with both sex and age, but amino nitrogen levels remained constant.

674. Moody, D. S.; Bottrell, D. G.; White, J. R.; and Newton, O. H. 1974. A programmable trapper for studying daily response patterns of boll weevils to pheromone-baited traps. Tex. Agric. Exp. Stn. Misc. Publ. 1164, 4 pp.

Research investigations require unique equipment that frequently cannot be purchased. To investigate many biological phenomena, specific devices must be conceived, designed and tested to determine insect responses and behavior. This boll weevil trap was constructed to determine the daily response patterns of boll weevils, Anthonomus grandis Boheman, to wing traps baited with male weevils or grandlure. Twelve yellow wing traps constructed of lightweight sheet metal coated with Stikem® are housed in the trapper within individual compartments on a time-controlled turntable. A timer controls the rotation of the turntable and the interval that each trap remains in position to catch weevils that respond to the males of grandlure. The trapper may be programed to allow daily catches of weevils at hourly or bihourly intervals.

675. ; Munoz, S. C.; Pettit, R. E.; and Bottrell, D. G. 1975. Relative toxicity of the fungus Aspergillus flavus to the male and female boll weevil. Tex. Agric. Exp. Stn. Prog Rep. PR-3307, 2 pp.

Studies are underway to determine the effectiveness of soil fungi in suppressing boll weevils. Practical boll weevil suppression strategies can perhaps be developed around the principle of sex specificity of pathogenic fungi. The fungus, Aspergillus flavus, exhibited sex specific toxicity to laboratory-

reared boll weevils, Anthonomus grandis. It caused significantly greater mortality (88.7 percent) in adult females than in adult males (22.8 percent). The fungus, A. parasiticus, caused very little mortality in either sex of weevils.

676. ; White, J. R.; and Bottrell, D. G. 1972. A machine for dispensing grandlure on cigarette filters used to bait boll weevil traps. J. Econ. Entomol. 65: 1215-1216.

Several formulations of the synthesized pheromone, grandlure, were tested as baits in wing traps placed in the field to attract and capture overwintered and late-season boll weevils. The most promising of these formulations were prepared by dispensing a solution (0.5 ml) of grandlure on a standard cigarette filter (8 x 30 mm). Traps baited with these filters (1/trap) were highly effective in capturing boll weevils in several recent tests (Hardee et al. 1972). The design and operation of a labor-saving machine that we constructed to treat filters with grandlure for trapping studies are described herein.

677. Moore, C. A., and Frazier, J. L. 1976. Partial characterization of acid phosphatases of the boll weevil, Anthonomus grandis. Insect Biochem. 6: 525-527.

Acid phosphatases from boll weevils, Anthonomus grandis have a pH optimum of 4.6 and a temperature of 37°C in 0.09 M citrate buffer. Enzyme activity is inhibited by 0.02 M fluoride (80%), arsenate (67%), and azide (24%), while activation by calcium and magnesium (5%) was considered nonsignificant. Activity of whole body homogenates is greater for females (31.8 μm/hr/mg protein) than for males (28.3 μm/hr/mg) and varies with adult age. Activity in supernatant and pellet fractions of ovaries was 53.4 and 50.0 μm/hr/mg, respectively, while corresponding activity for testes was 68.0 and 60.6 μm/hr/mg.

678. Moore, R. F. 1980. Apparatus for simultaneous determination of locomotor activity in multiple treatments of boll weevils. J. Econ. Entomol. 73: 795-797.

An apparatus is described that was designed to simultaneously determine with replication the locomotor activity of multiple groups of Anthonomus grandis grandis Boheman. In evaluation of the effects of the variables time for response, number of boll weevils per replication, time of day of test, age of weevils, and cleanliness ot test cages; optimum time for response was 20 min, optimum number of weevils per replication was 20 or less, and time of day of test, age of weevils, and cleanliness of test cages had no effect.

679. . 1980. Behavioral and biological effects of NRDC-161 as factors in control of the boll weevil. J. Econ. Entomol. 73: 265-267.

Methyl parathion applied topically was much more toxic to adult Anthonomus grandis grandis Boheman than NRDC-161 (S)-[cyano(3-phenoxyphenyl)methyl] cis-(+)-3-(2, 2-dibromoethenyl)-2, 2-dimethylcyclopropanecarboxylate), but NRDC-161 was more toxic to immature stages in laboratory media. NRDC-161 reduced fecundity of females, was repellent, and toxic to eggs at 0.01 ppm.

680. . 1980. Boll weevils: effect of insect growth regulators and juvenile hormone analogues on adult development. J. Ga. Entomol. Soc. 15: 227-231.

Boll weevils, Anthonomus grandis Boheman, lacking abdominal sclerotization were produced when 4th and 5th instars were fed diets containing from 0.01 to 100 ppm of one of the following chemicals: diflubenzuron; AI3-63223 (2, 6-difluoro-N-[[[4-trifluoromethyl)phenyl]amino]carbonyl]benzamide); HLR Ro-10-3108 (epofenonane) (2-ethyl-3-[3-ethyl-5-(4-ethylphenoxy)pentyl]-2-methyloxirane); and Hercules 24108 (1-methyl-2-propynl(4-chlorophenyl)carbamate).

681. ; Hopkins, A. R.; Taft, H. M.; and Anderson, L. L. 1967. Fatty acids in total lipid extracts of insecticide-treated boll weevils that survived or died. J. Econ. Entomol. 60: 64-68.

Boll weevils, Anthonomus grandis Boheman, from field collections or reared in the laboratory were treated topically or by a dry-film technique with toxaphene, toxaphene + DDT, carbaryl, or azinphosmethyl. Total lipids were extracted from weevils that survived and died from this treatment and the fatty acids in the extracts were determined. Analysis of the fatty acids with gas-liquid chromatography indicated significantly higher levels of stearic, linoleic, and linolenic acids in dead weevils and higher levels of palmitic and oleic acids in the survivors.

682. ; Leopold, R. A.; and Taft, H. M. 1978. Boll weevils: mechanism of transfer of diflubenzuron from male to female. J. Econ. Entomol. 71: 587-590.

Data show that is unlikely that copulation is the mechanism by which diflubenzuron is transferred from male to female boll weevils, Anthonomus grandis Boheman. Males treated by feeding on diets containing diflubenzuron were unable to transfer sufficient amounts to affect the hatch of eggs from untreated females. Studies with 14-C-labeled diflubenzuron showed that 3-10% of diflubenzuron applied externally was transferred between the sexes, but the testes of treated males contained insufficient diflubenzuron to affect hatch if the material were transferred to females. Diflubenzuron is apparently transferred between the sexes by physical contact; transfer by copulation seems highly improbable.

683. , and Taft, H. M. 1969. Effect of melatonin on egg production of the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 62: 252.

The effect of melatonin on egg production of the boll weevil was determined. It was found that 50 mg melatonin/100 g of diet, significantly reduced the number

of eggs produced throughout the 20 day test period.

684. ,.and Taft, H. M. 1971. Effect on reproduction of the boll weevil by drugs which act on catecholamines and indolealkylamines. Ann. Entomol. Soc. Am. 64: 1390-1393.

Anthonomus grandis Boheman were fed for 6 days on laboratory diets containing drugs known to affect levels of catecholamines and indolealkylamines in vertebrate nerve tissue; then they were fed diet without drugs for 6 more days. The effect on reproduction was determined by recording the number of eggs per female per day from the 3rd to the 12th day. The reduction in oviposition caused by alpha-methyltyrosine, alpha-methyl-m-tyrosine, 3-(p-chlorophenyl) alanine, imipramine hydrochloride, guanethidine sulfate, and chlorpromazine appeared to result from a reduction in feeding caused by a repellent effect. However, chloromethamphetamine and phenoxybenzamine reduced oviposition directly.

685. , and Taft, H. M. 1972. Relationship between phospholipids and triglycerides in the boll weevil and susceptibility to toxaphene + DDT. J. Econ. Entomol. 65: 1733-1735.

It was shown that field weevils are more susceptible to toxaphene:DDT than lab weevils, but by the F_3 generation on artificial diet they were comparable. Weevils surviving typical treatment with toxaphene:DDT were shown to contain more triglycerides but phospholipid comparable to the dead whether the weevils were from the field or laboratory.

686. , and Taft, H. M. 1975. Boll weevils: chemosterilization of both sexes with busulfan plus Thompson-Hayward TH-6040. J. Econ. Entomol. 68: 96-98.

Female Anthonomus grandis Boheman fed diets containing 0.1% busulfan are incompletely sterilized. Fertility is significantly decreased when insects fed

busulfan are dipped in 0.1% TH-6040 in acetone. The combined treatment should be valuable for sterilization of boll weevils in control programs which utilize sterile males.

687. ; Taft, H. M.; and Payne, L. B. 1970. Dimethyl sulfoxide as a possible synergist for selected insecticides against the boll weevil. J. Econ. Entomol. 63: 1342-1343.

The possibility that dimethyl sulfoxide (DMSO) would be synergist with some insecticides was tested. It was found that DMSO alone was more toxic than DDT alone and that it did not increase the effectiveness of azinphosmethyl, carbaryl, or toxaphene.

688. ; Whisnant, F. F.; and Taft, H. M. 1967. A laboratory diet containing egg albumin for larval and adult boll weevils. J. Econ. Entomol. 60: 237-241.

A laboratory diet for larval and adult boll weevils, Anthonomus grandis Boheman, was developed by substituting 3 g of egg albumin for the casein or soybean protein and 0.5 g/100 g diet of cotton leaf powder for the acetone cotton square powder or germinated cottonseed used in other diet. One % of a cottonseed:linseed oil mixture (1:1) was used in the adult diet and 0.5% in the larval diet. All components except the leaf powder are commercially available. A method of shaping and handling oviposition forms in large numbers is described. Two types of commercial spray egg albumin were evaluated as inducements to oviposition and as support for larval growth. Potassium sorbate and methyl parasept were used as inhibitors in the adult and larval diets. In excessive amounts, they reduced egg hatch and larval growth. The levels that prevented contamination but were not detrimental to propagation of the colony were determined.

689. Mori, K. 1978. Synthesis of the both enantiomers of grandisol, the boll weevil pheromone. Tetrahedron 34: 915-20.

Optically active forms of grandisol (2-isopropenyl-1-methylcyclobutane ethanol, I and I') were synthesized from optically active 5-carboxybicyclo[3.2.0]heptan-2-one (2 and its antipode), obtained by resolving the racemate. The optical purities of the synthetic products were determined by the NMR studies using a chiral shift reagent and shown to be 80%. The $[\alpha]_D$ values of our synthetic grandiols were ±20° (after correction) in accord with Magnus's synthetic (+)-grandisol (+ 18.5° after correction) and differed from that reported for the natural pheromone (+50±10°).

690. ; Tamade, S.; and Hedin, P. A. 1978. (-)-grandisol, the antipode of the boll weevil pheromone, is biologically active. Naturwissenschaften 65: 653-654.

(1R, 2S)-(+)-Grandisol (1) is one of the four pheromone components isolated from male boll weevils, Anthonomus grandis Boheman [1,2]. We synthesized its antipode and found it to be as biologically active as an isolated pheromone component. Antipodes of bioactive chiral molecules were generally believed to be devoid of biological activity. This dogma was proved to be untrue in the present case.

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691. Nemec, S. J. 1970. Topical applications and caged-plant evaluations of insecticide toxicities to bollworms, tobacco budworms and boll weevils. Tex. Agric. Exp. Stn. Consol. Prog. Rep. PR 2840-2845, pp. 14-18.

Laboratory tests were conducted to determine the toxicities of certain insecticides to the bollworm, Heliothis zea (Boddie), tobacco budworm, Heliothis virescens (F.) and boll weevil, Anthonomus grandis Boheman. Increased resistance in 1969 to methyl parathion and Azodrin was detected in tobacco budworms from Weslaco and College Station, Texas. The LD_{50} value for methyl parathion in 1969 increased 1 1/2-fold over 1968 and 3-fold over the 1967 LD_{50} value for tobacco budworms from the Brazos River Valley near College Station. The LD_{50} value of methyl parathion for tobacco budworms from Weslaco in 1969 was 2-fold greater than in 1968 and 5 1/2-fold greater than the LD50 value established for College Station larvae in 1967. Similar increases in resistance to Azodrin® by tobacco budworms from both areas of the state were also observed. The LD_{50} values obtained for the bollworm in 1969 did not change significantly from the LD_{50} values established during the previous 4 years. Therefore, the bollworm has developed no apparent resistance to methyl parathion or Azodrin. Most of the insecticides tested in caged plant tests produced effective control of bollworm larvae. These included the organophosphates methyl parathion, Azodrin and Monitor; the carbamate, Sevin, and certain mixtures of insecticides. The chlorinated hydrocarbon insecticides tested without the addition of organophosphorus insecticides were ineffective. Extremely high dosages of methyl parathion and Azodrin were required to kill significant percentages of tobacco budworms on sprayed cotton plants. The organophosphorus insecticides and a carbamate were the most toxic materials to boll weevils.

692. _____. 1971. Laboratory investigations of insecticide effectiveness against bollworms, tobacco budworms and boll weevils. Tex. Agric. Exp. Stn. Dep. Entomol. Tech. Rep. 19, pp. 33-37.

Laboratory studies were conducted to evaluate the toxicities of certain insecticides to the bollworm, Heliothis zea (Boddie), tobacco budworm, Heliothis virescens (F.) and boll weevil, Anthonomus grandis Boheman. Resistance to methyl parathion and monocrotophos by tobacco budworms from two areas of Texas was substantially greater in 1970 than in 1969. The LD_{50} value for methyl parathion for tobacco budworms from the Brazos Valley near College Station was twofold greater in 1970 than in 1969 and 14-fold greater than in 1964. The LD_{50} value established for methyl parathion for tobacco budworms from Weslaco in 1970 was 0.46 milligrams per gram. This value is almost fourfold greater than that established in 1969 and 46-fold greater than the LD_{50} established for tobacco budworms in 1964 from College Station. Similar increases in resistance to monocrotophos by tobacco budworms from both areas of the state were also observed. The LD_{50} values obtained for the bollworm in 1970 did not change significantly from the LD_{50} values established during the previous 7 years. This indicated that bollworms have not developed any detectable resistance to methyl parathion or monocrotophos. The organophosphorus and carbamate insecticides gave high mortalities of bollworms at moderate test dosages in caged plant tests. The chlorinated hydrocarbon compounds were generally ineffective against the bollworm when used singly, but when used in combination with methyl parathion their effectiveness was enhanced. Extremely large dosages of most insecticides did not provide adequate mortality of tobacco budworms on treated plants. The organophosphorus and carbamate insecticides were the most toxic materials to boll weevils.

693. . 1972. Resistance levels and results of laboratory insecticide tests for controlling bollworms, tobacco budworms and boll weevils. Tex. Agric. Exp. Stn. Prog. Rep. PR-3089, pp. 74-85.

Laboratory studies were conducted to evaluate the toxicities of certain insecticides to the bollworm, Heliothis zea (Boddie), tobacco budworm, Heliothis virescens (F.) and boll weevil, Anthonomus grandis Boheman. Resistance to methyl parathion and monocrotophos by tobacco budworms for 2 areas of Texas was about the same in 1971 as in 1970. The 1971 LD_{50} value for methyl parathion for tobacco budworms from the Brazos Valley near College Station was 0.11 (milligrams per gram; the LD_{50} value for budworms from Weslaco was 0.27 mg/g. Increased resistance to monocrotophos by tobacco budworms from College Station was observed. The LD_{50} values established for methyl parathion and monocrotophos for the bollworm in 1971 did not change significantly from the LD_{50} values established during the previous 7 years. This indicated that bollworms have not developed detectable resistance to the organophosphorus compounds. Extremely large dosages of most insecticides did not produce adequate mortality of tobacco budworms on treated plants. The organophosphorus and carbamate insecticides gave high mortalities of bollworms at moderate test dosages in caged plant tests. The chlorinated hydrocarbon compounds were generally ineffective against bollworms. All insecticides tested against boll weevils produced high mortalities.

694. , and Adkisson, P. L. 1968. Laboratory tests of effectiveness of certain insecticidal sprays for controlling the bollworm, budworm and boll weevil. Tex. Agric. Exp. Stn. Misc. Publ. MP-876, 7 pp.

Toxicities of several insecticides to bollworms, Heliothis zea (Bod.), tobacco budworms, Heliothis virescens (F.), and boll weevils, Anthonomus grandis Boh. were determined in laboratory studies during 1967. Methyl parathion and Azodrin were the most effective individual materials tested against the bollworm. Also,

mixtures of Strobane, toxaphene, endrin and Sevin with methyl parathion were effective against the bollworm. Methyl parathion and a mixture of Strobane-methyl parathion were the most effective insecticides tested against the tobacco budworm. Much greater dosages were required, however, to kill tobacco budworms than were needed to kill comparable numbers of bollworms. In fact, when DDT was added to mixtures containing chlorinated camphenes and methyl parathion, the resultant three-way mixtures killed fewer bollworms and tobacco budworms than did two-way mixtures of chlorinated camphene and methyl parathion without DDT. The most effective materials tested against boll weevils were the organophosphorus insecticides, Guthion, methyl parathion, Azodrin, Trithion and malathion. Sevin, a carbamate, also provided satisfactory control. The chlorinated hydrocarbons were the least effective materials tested against the boll weevils.

695. , and Adkisson, P. L. 1969. Effects of simulated rain and dew on the toxicity of certain ultra-low-volume insecticidal spray formulations. J. Econ. Entomol. 62: 71-73.

The effects of simulated rain and dew on the toxicity of ULV sprays of certain insecticide formulations to the bollworm, Heliothis zea (Boddie), and boll weevil, Anthonomus grandis Boheman, were investigated. Formulations compared with Azodrin® (3-hydroxy-N-methyl-cis-crotonacide dimethyl phosphate, 5 lb/gal water miscible), Azodrin (4.8 lb/gal low-volume concentrate), azinphosmethyl . lb/gal EC). azinphomethyl (2 lb/gal ULV), methyl parathion (80% T), methyl parathion (4 lb/gal ECO, malathion (96.5% T), and Strobane® (terpene polychlorinates, 65% chlorine) + methyl parathion (4 lb + 4 lb/gal EC). Results indicate that ULV sprays of water-miscible formulations were less toxic to the bollworm and boll weevil than immiscible formulations when subjected to rain and dew. Certain additives showed promise for enhancing the resistance to rain of an Azodrin formulation.

696. , and Adkisson, P. L. 1969. Laboratory tests of insecticides for bollworm, tobacco budworm and boll weevil control. Tex. Agric. Exp. Stn. Prog. Rep. 2670-2674, pp. 10-14.

Laboratory tests were conducted to determine insecticide toxicities to bollworms, Heliothis zea (Boddie), tobacco budworm, Heliothis virescens (F.) and boll weevils, Anthonomus grandis Boh. Methyl parathion, EPN and Azodrin or mixtures of these materials with each other proved highly toxic to bollworms. In addition, mixtures of certain chlorinated hydrocarbon insecticides with methyl parathion killed high percentages of the bollworms. The chlorinated hydrocarbon insecticides tested without the addition of organophosphorus insecticides were ineffective. The tobacco budworm population in the Lower Rio Grande Valley, and perhaps near College Station, has apparently developed a low-level resistance to the methyl parathion and Azodrin. Large dosages of these two insecticides were necessary to kill the tobacco budworms in laboratory tests involving sprayed cotton plants. In addition, LD_{50} values for methyl parathion as computed from dosage mortality lines indicated that the tobacco budworm has developed a 2.0-2.5-fold increase in resistance to methyl parathion during the past year. Similar increases by the budworm to Azodrin were also evident. There was no evidence that the bollworm has developed resistance to any of the organophosphorus insecticides. The organophosphorus insecticides were the materials most toxic to the boll weevil. Chlorinated hydrocarbon insecticides were relatively ineffecitve against the boll weevil; however, their toxicities were increased when they were used in combination with certain organophosphorus compounds.

697. Nettles, W. C., Jr. 1972. Toxic sugars and longevity of Anthonomus grandis. J. Insect Physiol. 18: 1107-1113.

Toxic sugars (D-arabionse, L-rhamnose, and L-sorbose) were fed to adults of the boll weevil, Anthonomus grandis. Based on longevity as a criterion, arabionose was the most toxic of the three sugars. When fed to newly emerged

adults, sucrose protected against arabionse poisoning. Increasing the sucrose content of the larval diet also decreased the toxicity of arabinose fed to newly emerged adults. Arabionse was less toxic to adults previously fed either cotton bolls, flower buds, or artificial diet pellets for 10 days than it was to unfed newly emerged adults. In boll-, bud-, and pellet-fed adults subsequently fed sugars, arabionose was about twice as toxic as L-rhamnose. Although there was no difference in mortality between sexes when newly emerged adults were fed arabinose and mixtures of arabinose and sucrose, among adult weevils previously fed either bolls, buds, or pellets the females were more susceptible than males to arabinose and rhamnose.

698. , and Betz, N. L. 1966. Surface sterilization of eggs of the boll weevil with cupric sulfate. J. Econ. Entomol. 59: 239.

We recommend the following procedure for surface sterilization of boll weevil eggs and have used it for more than 2 years with excellent results: place the eggs in 18% cupric sulfate for 3-5 min and then wash with sterile water. Allow the eggs to stand in a solution of 0.04% mercuric chloride in 25% ethanol for 2-3 min, wash the eggs with sterile water, and place them on the artificial larval medium. If the egg surface is thought to be contaminated with an unusually large number of microorganisms, better results are obtained when the eggs are held in 18% $CuSO_4$ longer than 3-5 min.

699. , and Betz, N. L. 1975. Lack of synergism when Strobane-DDT mixtures are injected into the boll weevil. J. Econ. Entomol. 68: 438-440.

Strong synergistic action was obtained following topical application of Strobane® (terpene polychlorinates [65% chlorine])-DDT (2:1) to 3 resistant strains of Anthonomus grandis Boheman. However, when mixtures of Strobane-DDT were injected, very little or no synergism was observed. Injfected DDT was more toxic than injected Strobane.

700. , and Burks, M. L. 1971. Absorption and metabolism of galactose and galactitol in Anthonomus grandis. J. Insect Physiol. 17: 1615-1623.

Galactitol is a significant metabolite of galactose in fasted adults of Anthonomus grandis; this is the first time that galactitol has been found to be a metabolite of galactose in an insect in vivo. Galactitol is not metabolized, and galactose, at best, is poorly metabolized by the boll weevil to trehalose and glycogen. Because sizeable quantities appear in the haemolymph when fed, galactose and galactitol must be readily absorbed through the gut.

701. , and Burks, M. L. 1973. Metabolism of sugars to polyols in the boll weevil. J. Insect Physiol. 19: 1677-1687.

When fed to starved adults of Anthonomus grandis, several pentoses and hexoses were metabolized to the corresponding polyols (sugar alcohols). Xylitol, galactitol, arabitol, ribitol, rhamnitol, mannitol, and sorbitol were metabolites of DOxylose, D-galactose and lactose, D-arabinose, D-ribose, L-rhamnose, D-mannose, and D-glucose and D-fructose, respectively. L-Sorbose was not metabolized to a polyol. Large quantities of xylitol and galactitol and intermediate amounts of arabitol, ribitol, and rhamnitol accumulated while only small amounts or traces of mannitol and sorbitol were detected. The limited accumulation of sorbitol in the glucose- and fructose-fed weevils probably was caused by the rapid metabolism of sorbitol to glucose, fructose, trehalose, and glycogen. Each of the ingested sugars, the corresponding polyols, and trehalose were present in the weevil haemolymph. Most of the polyols had never before been detected as metabolites in an insect.

702. ; Parro, B.; Sharbaugh, C.; and Mangum, C. L. 1972. Trehalose and other carbohydrates in diapausing and starving boll weevils. Ann. Entomol. Soc. Am. 65: 554-558.

Anthonomus grandis Boheman (Coleoptera: Curculionidae) was studied to determine the effects of diapause and starvation on trehalose and glycogen levels. When corrections were made for the greater dry weight of diapausing boll weevils, there was little if any difference in trehalose levels between diapausing and reproducing adults and between males and females. The effects of starvation also were small because trehalose levels in weevils starved for 12-20 hours were about normal. Glycogen may have been metabolized at a more rapid rate in starved reproducing than in stared diapausing weevils. But trehalose levels were maintained in weevils starved 12-20 hours because the trehalose content of reproducing weevils was equal to or slightly higher than that of diapausing weevils. On a dry-weight basis, glycogen levels in weevils fed bolls continually were greater in reproducing than in diapausing individuals. Because levels of glycogen and trehalose were no greater in diapausing than in reproducing weevils, the increased longevity of overwintering diapausing weevils cannot be caused by accumulations of glycogen or trehalose.

703. Newsom, L. D. 1967. Consequencies of insecticide use on nontarget organisms. Annu. Rev. Entomol. 12: 257-286.

General contamination of ecosystems with measurable amounts of chlorinated hydrocarbon insecticide residues has occurred during the last two decades. Since "pest" and "beneficial" are terms that have no biological validity, it is not surprising that both target and nontarget organisms have been affected and have responded in similar ways. Phenomena such as susceptibility, refactorines resistance, "resurgence" species displacement, specificity of response and concentration of residues are known among both. It is unrealistic to assume that "desirable" species will be eliminated while "pest" species will become more difficult to control.

704. . 1974. Pest management: history, current status and future progress. In F. G. Maxwell and F. A. Harris (eds.), Proceedings of the Summer Institute on Biological Control of Plant Insects and Diseases, pp. 1-18. University of Mississippi Press, University, Miss.

Discussions is concentrated on problems restricted for the most part to the southern United States, principally control of cotton insects and related pests with considerable emphasis on the control of the boll weevil.

705. . 1976. The elimination concept and its alternatives. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 149-153.

The effectiveness of a pest management system based on these components has been proved and demonstrated in large scale experiments. Other components that will improve the system's effectiveness can be added to it as they become available from additional research, e.g., release of sterilized boll weevils and use of resistant varieties. Such a system would have the added advantage of relaxing the selective pressure of insecticides on resistant populations of tobacco budworm and the bandedwing whitefly. It should prevent further development of resistance in these pests. Moreover, it is possible that relaxation of insecticide pressure on these two species would allow reasonably rapid reversion toward susceptibility to occur in resistant populations. The system would have only one element that would be cause for concern, namely, the possibility that enough selective pressure could be applied in diapause treatments to select populations resistant to the O-P insecticides. However, it would not be as likely to select for resistance to the O-P's as the eradication program that calls for the mandatory in-season treatment of all cotton acreage in phase I of the proposed scheme. Also, it is an encouraging fact that no appreciable levels of O-P resistance in the boll weevil have developed during almost two

decades of extensive and intensive in-season applications of these chemicals. Is it not a more reasonable approach to boll weevil control to adopt this proved method of pest management than to embark upon a concept that has been tested, and found to be a failure, in only one experiment? Funds saved could be devoted more appropriately to finding solutions to the problems that caused the Pilot Boll Weevil Eradication Experiment to be a failure.

706. Nilakhe, S. S. 1977. Boll weevils: sperm transfer by sterile vs. normal males: fecundity and the use of sperm by females. Ann. Entomol. Soc. Am. 70: 929-932.

Normal males of Anthonomus grandis grandis Boheman(Coleoptera: Curculionidae), were held unmated and then were mated once. The number of sperm transferred by them increased as they grew older, but with regards to the percentage of the available sperm transferred, the reverse was true. The 4-day-old males transferred ca. 1/5 as many sperm as the 14-day-old males; but the fecundity of the females mated to these males was ca. the same. Males treated with gamma irradiation alone or in combination with diflubenzuron, (1-(4-chlorophenyl) -3-(2,6-diflurobenzoyl)-urea) and held unmated for 5 days transferred ca. 3/4 of available sperm in a single mating. Both 9-day-old normal males and males treated with 8000 rad + diflubenzuron transferred ca. 1.5 million sperm to the females; however, the females mated to treated males had only ca. 1/2 as many sperm in their spermathecae as females mated to normal males. This is the 1st indication that irradiation lowers the quality of boll weevil sperm. Sperm from the spermathecae were utilized by the females at a much faster rate during the 1st 4 days after mating than during the 5th through the 10th day.

707. . 1977. Longevity and fecundity of female boll weevils placed with varying numbers of males. Ann. Entomol. Soc. Am. 70: 673-674.

The bursa copulatrix of female boll weevils, Anthonomus grandis Boheman, distended greatly and occupied nearly the entire abdomen due to repeated insemination when held with 20 to 40 ♂ was ca. 1/4, or less than when 1 ♀ was held with 1 ♂. Fecundity of a female held with 10 or more males was significantly less than that of a female held with 1 ♂.

708. . 1977. Sperm production in overwintered vs. sterile boll weevils and attractiveness of laboratory vs. overwintered males. J. Ga. Entomol. Soc. 12: 321-327.

Untreated males of Anthonomus grandis Boheman produced significantly greater numbers of sperm than males treated with different sterilizing procedures. Males given 0.09% busulfan (1,4-butanediol dimethanesulfonate) in adult diet produced 4.11 million sperm during their lifetime. Males treated with an acute dose of 8000 rad alone or in combination with 0.01% diflubenzuron, (N-[[4-chlorophenyl)amino]carbonyl]-2,6-diflurobenzamide), produced ca. 1/2 as many sperm as males treated with busulfan. Males fed 0.09% busulfan + 0.35% hempa (hexamethylphosphoric tramide) in the adult diet produced ca. 1/4 as many sperm as males treated with busulfan alone. Laboratory males produced ca. 2.4 times more sperm than overwintered males. Laboratory males were 2.5 times more attractive than overwintered males.

709. , and Earle, N. W. 1976. Mating frequency of normal vs. sterile male boll weevils in the laboratory. J. Econ. Entomol. 69: 454-461.

Male Anthonomus grandis Boheman, treated with a combination of γ-irradiation and hempa in the diet mated ca. one-half as often as untreated males when paired individually with 4 virgin females/day. Examination of spermathecae showed that females mated to treated males contained an average of ca. 1/3

as much sperm as females mated to untreated males. Thus, considering spermathecal filling and mating frequency, treated males transferred only ca. 1/6 as much sperm as untreated males. When paired with females immediately after treatment, treated males inseminated an average of 18.3 ♀ before aspermia occurred; however, when treated males were first held without females for 10 days, they were capable of inseminating an average of only 4.1 ♀.

710. , and Earle, N. W. 1976. Sperm production in normal vs. sterile boll weevils. J. Econ. Entomol. 69: 609-613.

Newly emerged normal males of Anthonomus grandis Boheman contained only 4000 (mena) sperm. Sperm production rapidly increased, reaching a fairly constant rate of ca. 1.38 million sperm/day after 6-7 days. All sterilization treatments drastically reduced sperm production. Males treated as adults with average fractionated dose of 6800 rad produced 2.66 million sperm during their life time. Weevils treated with fractionated doses of 4000 rad combined with adult feeding on 0.2% hempa diet, and males treated with average fractionated doses of 5850 rad produced ca. 3/4 and 1/5 as many sperm as males irradiated as adults with average fractionated doses of 6800 rad, respectively. Males irradiated as pupae with a fractionated dose of 6300 rad inseminated ca. 1/2 as many females as males that received the same treatment as adults. When treated males were held without females for 3 days or more, they inseminated only ca. 1/2 as many females as males that were provided females immediately after treatment.

711. ; Earle, N. W.; and Villavaso, E. J. 1978. Effect of release time on recovery of tagged irradiated boll weevils. J. Econ. Entomol. 71: 401-402.

Irradiated Anthonomus grandis Boheman, tagged with ^{32}P, were hand-released in cotton fields during the morning, noon, and evening. Equal numbers of boll weevils were recovered irrespective of release time. Within 1 day after release, ca. 1/3 of all released weevils had disappeared from the field; by the 4th day, only 38.0% live weevils were recovered. Tagging did not reduce survival of irradiated weevils.

712. , and Villavaso, E. J. 1979. Measuring sperm competition in the boll weevil by the use of females whose spermathecae have been surgically removed. Ann. Entomol. Soc. Am. 72: 500-502.

A test was devised by which sperm competition could be measured directly in boll weevils, Anthonomus grandis grandis Boheman. Spermathecae were surgically removed from the females, and these females were allowed to mate with irradiated, then non-irradiated males and vice versa, with only 4 h separating the matings. By this method, we could use egg hatch data to measure sperm competitiveness without being concerned about the unknown effect that sperm stored in the spermatheca would have on egg hatch. Sperm from both types of males were found to be equally competitive. The presence or absence of the spermatheca apparently had no effect on egg hatch during the 1st 5 days mating.

713. Niles, G. A.; Harvey, L. H.; and Walker, J. K. 1978. Cultural control of the boll weevil. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 23-38.

Four decades cultural techniques have been advocated and practiced as key elements in control and management of the boll weevil (Anthonomus grandis B). Since the advent of the boll weevil in the 1890's a wide variety of cultural

practices have been employed; certain of these have persisted while others were discarded as ineffective, impractical, or uneconomical. The following general description of the background and evolution of cultural controls should serve to indicate the extent to which the practices may be utilized in boll weevil control and management systems.

714. Norman, J. W., Jr.; Henson, J. L.; Wolfenbarger, D. A.; Harding, J. A.; Gage, E. V.; Parker, R. D., Jr.; and Collins, G. 1979. Effects of water management practices on economics of insect control on cotton, Lower Rio Grande Valley, Texas. J. Econ. Entomol. 72: 367-370.

Data from a pest management program on cotton in dryland and irrigated conditions was used to develop an economic evaluation of insect control in the Lower Rio Grande Valley of Texas during 1973-75. A strong economic advantage was shown for dryland production. Dryland cotton had 89% of its harvested bolls set by June 19 while irrigated cotton had 88% set by July 17; thus, irrigation delayed maturity. Dryland cotton required 5.5 kg/ha (4.91 lb/acre) less insecticide AI than irrigated cotton. Lint yields for dryland cotton were 541 kg/ha (483 lb/acre) vs. 615 kg/ha (549 lb/acre) for irrigated cotton and were equal by statistical analysis. However, production costs for dryland cotton were $266.88/ha ($108.05/acre) less than irrigated cotton and dryland cotton returned net profits of $142.99/ha ($57.89/acre) above those of irrigated cotton.

715. Norment, B. R. and Chambers, H. W. 1970. Joint actions in organophosphorus poisoning in boll weevils. J. Econ. Entomol. 63: 499-502.

To analyze the joint action of binary mixtures, a laboratory culture of organophosphorus-susceptible boll weevils, Anthonomus grandis Boheman, were exposed to insecticides, defoliants, and equitoxic insecticide-defoliant mixtures. The degree of interaction in a susceptible strain of boll weevils was greater than unity for equitoxic binary mixtures of DEF® (S, S, S-tributyl phosphorotrithioate)

with methyl parathion, azinphosmethyl, malathion, and EPN®, (O-theyl O-p-nitrophenyl phenylphosphonothioate) indicating potentiation of toxicity. It was not possible, however, to attribute significance to the numerical degree of interaction since the mechanism of potnetiation in these mixtures is unknown. The potentiation of methyl parathion by DEF was not supported by statistical evidence, indicating that the addition of DEF may not necessarily result in greater-than-additive toxicity. The potentiating effects of DEF with malathion have previously been attributed largely to inhibition of aliesterase, a type of carboxyesterase. Conversely, EPN, azinphosmethyl, and methyl parathion lack carboxylic ester moieties, and the importance of aliesterase is questionable.

716. , and Chambers, H. W. 1970. Temperature relationships in organophosphorus poisoning in boll weevils. J. Econ. Entomol. 63: 502-504.

A laboratory culture or organophosphorus-susceptible boll weevils are exposed at different temperatures to cotton leaves or filter-paper discs previously treated with insecticide or defoliant. All materials examined showed a positive temperature coefficient of toxicity with methyl parathion and malathion being the most toxic at all temperatures. The toxicities of azinphosmethyl and EPN® (O-ethyl O-p-nitrophenyl phenylphosphonothioate) were severly decreased at 10°C while DEF® (S, S, S-tributyl phosphorotrithioate) showed appreciable toxicity only at 32°C. Studies involving different exposure and holding temperatures indicated that a higher exposure temperature results in increased toxicity, even though the holding temperature is the same for all treatments. Although transferring the insects to a low holding temperature from a high exposure temperature decreased the effectiveness of the toxicant, the corrected mortality of the insects exposed at 32°C and held at 10°C was more than twice that of those exposed and held at 10°C. These data suggest that temperature may affect both the innate toxicity and the rate of absorption of the insecticide into the insect.

O

717. Oliver, J. E.; Brown, R. T.; Stokes, J. B.; and McHaffey, D. G. 1973. Chemosterilants against the boll weevil. 4. Miscellaneous compounds. J. Econ. Entomol. 66: 796-798.

Recent reports from this laboratory described the sterilant activity of 3 classes of compounds, aziridines (Borkovec et al. 1972), s-triazines (DeMilo et al. 1972), and phosphoramides (Terry et al. 1972), against the boll weevil, Anthonomus grandis Boheman. We report here 40 additional active compounds including several amines and amine salts (I-13), dithiobiurets, dithiazolium salts, and related compounds (14-26), and miscellaneous heterocyclic compounds (27-39).

718. ; DeMilo, A. B.; Brown, R. T.; and McHaffey, D. G. 1977. AI3-63223: a highly effective boll weevil sterilant. J. Econ. Entomol. 70: 286-288.

Female Anthonomus grandis Boheman are effectively sterilized for as long as 8 wk when dipped in acetone solutions of AI3-63223 [1-(2,6-difluorobenzoyl)-3-[4-trifluoromethyl)phenyl]urea]. This compound is superior to diflubenzuron from which recovery of fertility occurs after 2-3 weeks. Considerable reduction of reproduction also occurs with male boll weevils similarly treated with AI3-63223.

719. Ourth, D. L., and Smalley, D. L. 1980. Phagocytic and humoral immunity of the adult cotton boll weevil, Anthonomus grandis, Coleoptera: Curculionidae, to Serratia-marcescens. J. Invertebr. Pathol. 36: 104-112.

This investigation determined phagocytic, lysozymal and bactericidal defensive responses of adult laboratory-reared cotton boll weevils, A. grandis. Phagocytosis was 1st demonstrated in boll weevils at 3 h following injection of live S. marcescens. Maximum phagocytosis occurred in 16.4% of plasmatocytes

at the end of 16 h postinjection. Lysozyme activity was demonstrated in both inoculated and uninoculated boll weevils. Peak lysozyme activity of 6.9 mu. g/ml was found at 48 h following inoculation of heat-killed S. marcescens. Bactericidal activity was demonstrated in inoculated boll weevils but not in uninoculated boll weevils. Peak bactericidal activity occurred at 24 h following inoculation of heat-killed S. marcescens. Lysozymal and bactericidal activities were shown to be separate functions.

P

720. Parencia, C. R., Jr. 1968. Control of cotton insects with an insect-collecting machine. J. Econ. Entomol. 61: 274-279.

A total of 7950 insects representing 9 orders, 44 families, and 127 species were collected in 6 samples with an insect-collecting machine; also 313 spiders were collected. The cotton fleahopper, Psallus seriatus (Reuter), was the most abundant injurious insect, and the rapid plant bug, Adelphocoris rapidus (Say), was second. Boll weevils, Anthonomus grandis Boheman, were collected at the rate of 46 per acre, even though 1944 was not considered a "weevil" year. The machine collected 70% of the estimated population of boll weevils, 77% of the cotton fleahopper adults, and 80% of the rapid plant bug adults in first-run operations. In field-plot tests, the machine reduced populations of cotton fleahoppers and rapid plant bugs below those of the check, but a mixture of calcium arsentate and sulfur dust gave better control. The machine could not be used when plants became large and did not compete with insecticides in controlling migrating cotton fleahoppers when it was operated on the 5- to 7-day interval used to apply the insecticides. Also, the machine treated only a small portion of the cotton plant. It was most efficient in collecting cotton fleahopper adults and boll weevils when the cotton plants were in the presquare stage.

721. . 1968. Waging war on insects. Cotton Int. Ed. 35: 52, 53, 71.

The control of cotton insects before 1940 was obtained with inorganic insecticides applied in dust formulations. With the advent of the organic insecticides in the 1940's and their formulation as emulsifiable concentrates, they were applied as sprays thereafter. Further improvement was made with the development of the application of ultra-low volume technical undiluted materials. The organochlorine and organophosphorus and later carbamate compounds considerably improved control of insects attacking cotton which included thrips, cotton aphids, spider mites, boll weevils, bollworms, tobacco budworms, cotton leafworms, pink bollworms, cotton fleahoppers, plant bugs, cotton leaf perforators and minor pests of cotton. Control techniques were applied to early- and in mid- or late-season depending on insect infestations during those stages of cotton plant growth.

722. . 1975. Research on measures to control cotton insects in the United States of America. In Measures to Combat Insects, Document 8, 34th Plenary Meeting of the International Cotton Advisory Committee, Abidjan, Ivory Coast, (Nov. 1975), pp. 75-123 [Mimeogr.].

Cotton is grown from California in the West to the Carolinas in the East. The principal injurious insects include the boll weevil, Anthonomus grandis Boheman; bollworm, Heliothis zea (Boddie); tobacco budworm, H. virescens (F.); pink bollworm, Pectinophora gossypiella (Saunders); cotton fleahopper, Pseudatomoscelis seriatus (Reuter); cotton aphid, Aphis gossypii Glover; and lygus bugs, Lygus hesperus Knight and L. lineolaris (Palisot de Beauvois). A number of other insects and spider mites, Tetranychus spp., occasionally cause damage. Insecticides have been and will continue to be the principal means of controlling insects in the foreseeable future. However, because of rising costs, increasing resistance in insects to insecticides and environmental considerations, emphasis is being placed on other approaches to insect control. When such approaches to control

are used with insecticides they are referred to as integrated control, total populations suppression, or more recently, pest population management.

723. . 1976. Events leading to the Pilot Boll Weevil Eradication Experiment. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 59-61.

The boll weevil, Anthonomus grandis Boheman, entered the United States in 1892 and reached the Carolinas in 1922. Establishment of the Boll Weevil Research Laboratory in 1962 and strengthening of on-going research at several ARS and State Experiment Stations resulted in; (1) improved techniques for mass rearing the boll weevil; (2) development of the reproduction-diapause boll weevil suppression program; (3) development of ultra-low-volume sprays of insecticides; (4) development of the systemic insecticide, aldicarb; (5) identification and synthesis of grandlure for use in traps to capture boll weevils; and (6) progress in developing a chemosterilant to produce sterile males for release. The progress made and the importance and urgency of eliminating the boll weevil problem as soon as it became technically and operationally feasible resulted in the Pilot Boll Weevil Eradication Experiment being conducted in South Mississippi and adjacent cotton acreages in Alabama and Louisiana in 1971-1973.

724. . 1976. A history of the Waco, Texas, Cotton Insects Research Laboratory, 1939-1973. Bull. Entomol. Soc. Am. 22: 17-19.

The Blacklands Cotton-Insects Investigations Laboratory, so named in 1969, previously known as the Waco Cotton Insects Research Laboratory, was established at Waco, TX, in March, 1939, under the direction of K. P. Ewing. Its objective was to develop control measures for the bollworm, Heliothis zea (Boddie) and the cotton fleahopper, Pseudatomocelis seriatus (Reuter) that could be used in the large

cotton producing area encompassing the Texas Blacklands. It continued in operation for 34 years and was closed June 30, 1973. In this brief history of the Waco Cotton Insects Laboratory, the author hoped to point out the impact of its research on the control of cotton insects. Although much of the research mentioned was, also, conducted at other ARS Cotton Insect and State Agricultural Experiment Station Laboratories, the Waco Laboratory either had a first in many new innovations or exerted leadership in their development. Certainly, its research contributed greatly to the grower's arsenal in his fight with cotton insects.

725. . 1976. The Pilot Boll Weevil Eradication Experiment. In Proceed. of the Eighth Annual NE Forest-Insect Work Conference. Techniques for Research Development and Application, U.S. For. Serv. Gen. Tech. Rep. 27, pp. 3-6. North Haven, Conn.

The Pilot Boll Weevil Eradication Experiment was conducted cooperatively with 16 federal, state, and cotton-industry agencies from July, 1971 to August, 1973. Population suppression components were late-season insecticide treatments, cultural practices, pheromone traps, insecticide treatment when plants began to square, in-season insecticide treatments, and release of sexually-sterile male boll weevils. After studying the data on completion of the Experiment, the Technical Guidance Committee concluded "that it is technically and operationally feasible to eliminate the boll weevil as an economic pest in the United States by use of ecologically acceptable techniques."

726. . 1978. One hundred twenty years of research on cotton insects in the United States. U.S. Dep. Agric. Agric. Handb. 515, 75 pp.

This handbook consists of a brief discussion of progress made in research on the various cotton insects. The first section covers the period 1854 to 1940 and lists cotton insects and research achievements about each of them. The last section lists areas of research about all insects attacking cotton from 1941

to 1974. The outstanding research findings reported by authors of Federal and State agencies are summarized here, including some unpublished observations.

727. . 1980. Highlights of the Cotton Insect Research and Control Conference. Proc. 1980 Beltwide Cotton Prod.-Mech. Conf., pp. 18-20.

After several hard winters the boll weevil made a comeback in most infested states. Improvements were made in packaging and shipping irradiated boll weevils. One in-field trap per acre detected 2 of 4 boll weevil clumps and 4 traps per acre detected 4 of 4 clumps in the F_1 generation, with both arrangements detecting all of the reproducing weevil clumps in the F_2 generation. Infestations of bollworms and tobacco budworms were light to moderate. Traps baited with new 7-component synthetic pheromone of the tobacco budworm captured more moths than traps baited with virgin females. A new pyrethroid, AC22705, and thiodicarb showed promise against Heliothis spp. For the second year the cotton leafworm made its appearance in the midsouth and southeast. Infestations of the tarnished plant bug were higher and persisted longer into the season than usual in the midsouth. The estimated Beltwide loss to the 1979 cotton crop caused by insects was estimated to be 8.7 percent.

728. , and Cowan, C. B., Jr. 1972. Comparative yields of cotton in treated and untreated plots in insect-control experiments in central Texas, 1939-1970. J. Econ. Entomol. 65: 480-481.

In field experiments conducted for control of cotton insects in Central Texas during the 32-year period 1939-1970, an average of 6 applications of insecticides gave an increase in yield of 366 pounds of seed cotton per acre or 54.3%.

729. Parker, R. D.; Walker, J. K.; Niles, G. A.; and Mulkey, J. R. 1978. The Short-season effect in cotton and escape from the boll weevil. Tex. Agric. Exp. Stn. Bull. B-1315, 45 pp.

Experiments were conducted in Texas from 1975 through 1976 to investigate the place and value of rapid-fruiting cottons in production schemes directed at minimizing damage from the boll weevil, Anthonomus grandis Boheman. Narrow-row planting and the selection of certain genotypes produced more cotton bolls earlier in the season and increased yields. The benefits of genotype selection depended on the length of time during the bloom and boll set period that injurious numbers of weevils were delayed. Short-season types were more productive than their long-season counterparts in cases where the weevil-free period was shorter; however, where weevils were delayed the slower-fruiting cottons produced equally well. Susceptibility to boll-lock injury increased daily as bolls developed from later flowers following initiation of blooming. Seventy percent or more of the lint harvested (500-750 pounds of lint per acre) was produced from flowers of the first 3 weeks of blooming. It is during this critical time period that significant boll weevil damage to squares must be prevented if a satisfactory yield (500-750 pounds of lint per acre) is to be obtained without initiation of costly late-season insecticide applications.

730. Parrott, W. L.; Jenkins, J. N.; and Buford, W. T. 1970. Instars and duration of stadia of boll weevil larvae. Ann. Entomol. Soc. Am. 63: 1265-1267.

Measurement of the head capsules of larval Anthonomus grandis Boheman (Coleoptera: Curculionidae) demonstrated that the insect has 3 well-defined instars. The mean widths of the head capsule for thelst, 2nd, and 3rd instars were 0.41, 0.62, and 0.99 mm, respectively. When eggs were candled, placed in larval diet, and held in an incubator at 29.4°C and 50% RH, 95% of the eggs hatched within 6

hours. The 1st molt occurred between 36 and 42, and the 2nd between 66 and 78 hours after the eggs were candled and placed in the diet.

731. ; Jenkins, J. N.; and Smith, D. B. 1973. Frego bract cotton and normal bract cotton: how morphology affects control of boll weevils by insecticides. J. Econ. Entomol. 66: 223-225.

Azinphosmethyl and methyl parathion applied at 0.125 pound per acre left greater deposits and caused higher mortality of Anthonomus grandis Boheman on frego bract than on normal bract cotton squares when: (1) weevils were caged in the field on the 2 types of cotton, (2) weevils were placed in 1-pint cartons with squares removed from the plant after spraying, and (3) when weevils were placed in cartons with squares sprayed after being picked from the plant. These results were confirmed by recovery of approximately 7 times the amount of residue from frego than from normal bract buds sprayed with methyl parathion.

732. ; Maxwell, F. G.; and Jenkins, J. N. 1966. Feeding and oviposition of the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae), on the rose-of-Sharon, an alternate host. Ann. Entomol. Soc. Am. 59: 547-550.

The calyx that enclosed the developing bud of the rose-of-Sharon (Hibiscus syriacus L.) until the prebloom stage deterred feeding and oviposition of the boll weevil, Anthonomus grandis Boheman, on this alternate host. When the calyxes were removed, weevils fed on and oviposited in the buds at about the same rate as on flower buds (squares) of cotton. Although the calyxes were not a morphological barrier, they contained a substance that discouraged weevil feeding and oviposition during the bud stage of development and contributed to rose-of-Sharon's undesirability as a host. Field observations showed that infestation of rose-of-Sharon by the boll weevil occurs only when the plant grows near cotton.

733. ; Maxwell, F. G.; and Jenkins, J. N. 1969. Hampea sp., host of the boll weevil. II. Laboratory antibiosis studies. Ann. Entomol. Soc. Am. 62: 976-978.

Anthonomus grandis Boheman developmental studies were conducted on diets of freeze-dried cotton buds, Gossypium hirsutum L., and buds and capsules of Hampea sp., a dioecious host, using the laboratory strain of weevils and a wild strain collected from Hampea. A high degree of larval antibiosis was found in Hampea. It was more pronounced in female buds and capsules than in male buds. On diets from male buds and female buds and capsules, smaller adults and a longer developmental time were observed. However, the percent adult emergence of the laboratory, but not the Hampea strain of weevils, from male bud diets was about equal to cotton diets. In the female buds and capsules the antibiosis was also expressed as high larval mortality. The 2 strains of weevils were physiologically different in their growth and development on all diets. Quantitative chemical analysis of gossypol, ascorbic acid, total sugars, and reducing sugars in the male and female buds and capsules failed to show that any of these materials except possibly gossypol was related to the expressed resistance. Thus, some unknown toxic factor rather than nutrition is suspected as the cause of antibiosis.

734. ; Maxwell, F. G.; Jenkins, J. N.; and Hardee, D. D. 1969. Preference studies with hosts and nonhosts of the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 62: 261-264.

Tests were made to determine the presence of feeding stimulants and attractants for Anthonomus grandis Boheman in aqueous extracts of host and nonhost species of the family Malvaceae including cotton, Gossypium hirsutum L. The host plants found infested most frequently in nature generally contained the highest concentrations of feeding stimulant and attractant. Also, all known plants except Hibiscus syriacus L. attacked in nature by the boll weevil contained gossypol.

Thus, plants containing gossypol seem preferred, but its presence does not appear to be an absolute requirement for host acceptability. Of the species tested, Cienfuegosia sulphurea (St. Hill.) Garki and Thespesia populnca (L.) Soland ex Carrea seemed the most suitable wild hosts next to cotton. H. syriacus again was not preferred. However, late in the season when it is near cotton it is sometimes attacked. For this reason, and because of its wide geographical distribution and general abundance as an ornamental throughout the Cotton Belt, it is the most important of the alternative hosts to consider in any future eradication programs against the boll weevil.

735. ; Maxwell, F. G.; Jenkins, J. N.; and Mauldin, J. K. 1969. Amino acids in hosts and nonhosts of the boll weevil, Anthonomus grandis. Ann. Entomol. Soc. Am. 62: 255-260.

Protein and nonprotein amino acids were detected in the buds of several hosts and nonhosts of Anthonomus grandis Boheman by ion exchange chromatography, and identifications were confirmed by thin-layer chromatography. Twenty-three amino acids plus ammonia were identified in the cotton samples, including 5 that had not been previously reported in cotton buds. These 5 were: beta-alanine, cysteic acid, ethanolamine, glucosamine, and taurine. Concentrations were always greater in the protein samples. All plant buds analyzed contained 9 of the 10 amino acids essential for the weevil. A microbiological assay detected tryptophan in cotton bud tissue. Amino acid profiles of these hosts and nonhosts were established. There were not sufficient qualitiative and quantitative differences in the amino acids to explain the host and nonhost status.

736. Pelletier, S. W., and Mody, N. V. 1976. A facile synthesis of the cyclohexyl constituents of the boll weevil sex pheromone. J. Org. Chem. 41: 1069-1071.

The four monoterpene compounds [(E)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde

(1), (Z)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (2), (Z)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol (3), and (+)-cis-2-isopropenyl-1-methyl-cyclobutaneethanol 4)] that comprise the pheromone of male boll weevil Anthonomus grandis Boheman were identified and first synthesized by Tumlinson et al. These sex attractants are currently of considerable interest since they may provide a generally non-toxic method of surveying and controlling boll weevil population. The growing concern over the environmental pollution and ecological imbalance caused by insecticides has further stimulated interest in this area. The commercial importance of these sex attractants prompted us to develop an efficient, high-yield synthesis of these compounds. This paper describes a facile route from commercially available 3-methyl-2-cyclohexenone to the E and Z aldehyde components (1 and 2) in 80% overall yields. Separation of the aldehyde mixture, followed by reduction of aldehyde 2 with $NaBH_4$ or 9-BBN, affords a route to the component Z alcohol (3) in an essentially quantitative yield. Scheme I outlines the synthesis of sex pheromone components 1, 2, and 3.

737. Pfrimmer, T. R. 1966. Systemic insecticides for cotton insect control in 1965. J. Econ. Entomol. 59: 1113-1118.

Systemic insecticides were evaluated for effect on insect control, plant stand, and early fruiting of cotton in field tests at Stoneville, Mississippi in 1965. A granular formulation of Union Carbide UC-21149 [2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl)oxime] applied with the seed at planting gave outstanding control of tobacco thrips, Frankliniella fusca (Hinds), and was effective against the tarnished plant bug, Lygus lineolaris (Palisot de Beauvois). Granular formulations of General Chemical GC-6506 [dimethyl p-(methylthio)phenyl phosphate] and Niagara NIA-10242 (2,3-dihydro-2,2-dimethylbenzofuranyl methylcarbamate) applied with the seed at planting were not so effective as UC-21149. When NIA-10242 and UC-21149

were applied to the seed, they were less effective against thrips than when they were applied in a granular formulation with the seed at planting. Granular formulations of UC-21149 applied as a side-dressing gave good control of caged boll weevils, Anthonomus grandis Boheman, and better suppression of the two-spotted spider mite, Tetranychus urticae (Koch), than the other materials tested. Granular formulations applied with the seed at planting did not adversely affect seed germination and emergence of plants, but the higher rates of treatment reduced stands later. Treatment of the seed did adversely affect germination and/or emergence. Control of thrips resulted in earlier fruiting of plants, but yields usually were not increased.

738. . 1968. Field tests with in-furrow and seed treatments of systemic insecticides on cotton at Stoneville, Mississippi. J. Econ. Entomol. 61: 1607-1612.

Systemic insectides were evaluated for effect on insect control, plant stand, early fruiting, and yield of cotton in 1966 and 1967. Granular formulations of disulfoton, phorate, Allied Chemical GC-6506 (dimethyl p-(methylthio)phenyl phosphate), Hercules 13462 (O,O-dimethyl phosphorodithioate S-ester with N-(1-mercaptoethyl) succinimide), Niagara NIA-10242 (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate), and Union Carbide US-21149 (2-methyl-2-(methylthio) Propionaldehyde O-(methylcarbamoyl) oxime) applied with the seed at planting gave good initial control of tobacco thrips, Frankliniella fusca (Hinds); UC-21149 gave the best residual control. Seed treated with Azodrin® (3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate), disulfoton, methomyl, Hercules 13462, and NIA-10242 gave fair to good initial control of thrips. Populations of other insect species did not become a problem. The treatments reduced stands in some tests but not in others. The control of thrips that was achieved with the sys-

temic insecticides resulted in earlier fruiting of plants in 3 of the 6 tests, but yields increased as a result in only 1 test.

739. ; Furr, R. E.; and Stadelbacher, E. A. 1971. Materials for control of boll weevils, bollworms, and tobacco budworms on cotton at Stoneville, Mississippi. J. Econ. Entomol. 64: 475-478.

When experimental insecticides were evaluated for control of boll weevils, Anthonomus grandis Boheman; bollworms, Heliothis zea (Boddie); and tobacco budworms, H. virescens (F.), on cotton in field-plot tests at Stoneville, Miss. in 1969, CIBA C-9491 (O-(2, 5-dichloro-4-iodophenyl) O, O-dimethyl phosphorothioate) and Velsicol VCS-506 (O-(4-bromo-2, 5-dichlorophenyl) O-methyl phenylphosphonothioate) applied as conventional emulsifiable concentrate sprays gave control of Heliothis spp., primarily tobacco budworms, comparable to the standard treatment. Several other materials including formulations of Bacillus thuringiensis Berliner wer less effective. Ultra low volume (1/2 gal or less/acre) sprays of EPN (O-ethyl O-p-nitrophenyl phenylphosphonothioate), EPN + methyl parathion, malathion + methyl parathion, methyl parathion, and toxaphene + DDT + methyl parathion gave very good control of Heliothis. Control of the Heliothis resulted in increases in yield of as much as a bale of seed cotton/acre.

740. Phillips, J. R. 1976. Diapause as it relates to the boll weevil, Anthonomus grandis Boheman. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 10-11.

These data support the assumption that the weevil in its northward movement has adapted to photoperiod as an indicator of season but has also retained the capacity to "read" its host, no doubt a characteristic that evolved around the occurrence of dry- and wet-season conditions that exist south of the border.

Thus, we seem to have an aestival diapause weevil (responding to host) and a hibernal diapausing weevil (responding to photoperiod).

741. , and Carter, F. L. 1978. Complexity of diapause in the boll weevil, Anthonomus grandis Boheman. Proc. Entomol. Conf. Cronobiology, 12th. Cronobiology Suppl., pp. 621-626.

Studies in Arkansas showed that boll weevil diapause was affected by changes in fruiting activity of the cotton plant. Generally, when larval development occurred while fruiting levels were increasing or being held at a high level, diapause in resulting adults was low (0-20%). Diapause ranged from 20-50% when larval development coincided with decreasing fruiting levels, and was at least 50% as the crop approached maturity. These data show that the boll weevil not only responds to short photoperiods, that are characteristic during the fall in the temperate zones, but it may also respond to changes in fruiting activity through the season. These studies also suggested that the boll weevil may utilize a chemical messenger, abscisic acid, in the plant as an indicator of seasonal conditions. When 0.01 ppm of ABA was added to synthetic medium in the laboratory, it had a significant effect on diapause response and fecundity of the boll weevil.

742. Pieters, E. P. 1976. Chemical control of overwintering boll weevils in the Coastal Bend area of Texas. Tex. Agric. Exp. Stn. Prog. Rep. PR-3419, 1 p.

Two insecticide treatments aimed at reducing overwintering boll weevil populations were applied to five fields during 1975. Damaging boll weevil population levels developed in the untreated check in only two of the five fields. In a field where boll weevil populations did develop and where no additional insecticides were applied to control fleahoppers, the treated plot had significantly fewer boll weevils damaged squares and fewer fleahoppers. The number of

Heliothis spp. larvae and damaged squares was greater in the treated plot, while no significant differences were observed in the number of beneficial arthropods.

743. . 1976. Movement of boll weevils to fall trap crops. J. Econ. Entomol. 69: 189-191.

Adults of Anthonomus grandis Boheman moved into trap crops established during the period when the cotton was being harvested. These "fall trap crops" were specific rows within the cotton field which remained unmodified during the harvest procedure while the remaining portion of the field was treated and harvested in the normal manner. Trap crops established in picker-harvested fields attracted the greatest number of adult boll weevils. This was especially true of trap crops augmented with synthetic pheromone, Grandlure®. Less movement of weevil adults into fall trap crops established in stripper-harvested fields was observed. The greatest amount of movement into fall trap crops occurred during the initial 24 h after the trap crops were established.

744. , and Bird, L. S. 1977. Field studies of boll weevil resistant cotton lines possessing the okra leaf-frego bract characters. Crop Sci. 17: 431-433.

Cotton lines (Gossypium hirsutum L.) possessing the okra leaf ($L^{o}L^{o}$) - frego bract (fg fg) characters were evaluated in a 3-year field study in the Coastal Bend area of Texas. Two locations were used in 1974 and 1975 and one location in 1976. The number of squares (flower buds) with boll weevil (Anthonomus grandis Boheman) ovipositional punctures was recorded on a total of forty cotton lines. Cotton lines possessing the okra leaf-frego bract characters averaged about 60% fewer boll weevil ovipositional punctured squares than the broad leaf - normal bract cottons.

745. , and Sterling, W. L. 1973. Inferences on the dispersion of cotton arthropods in Texas. Environ. Entomol. 2: 863-867.

Discrete frequency distributions obtained from samples of various arthropods commonly found in Texas cotton fields were fitted to 6 discrete mathematical frequency-distribution models. The observed frequency distributions most frequently fit the negative binomial expectations, suggesting a clumped pattern of dispersion. These same arthropods were seldom observed to be randomly dispersed as indicated by poor agreement with the Poisson expectations.

746. , and Sterling, W. L. 1973. Sampling techniques for cotton arthropods in Texas. Tex. Agric. Exp. Stn. Misc. Publ. MP-1110, 8 pp.

The D-Vac® sampling method generally provided a better estimate of arthropod abundance than visual in situ whole plant examination for most cotton arthropods in studies in 1971-72. Exceptions included the sampling of Heliothis spp. larvae and eggs, boll weevils and plant parts. For these units, the visual whole plant examination method was preferred. Three sample unit sizes were compared during 1972: a) single plant, b) 1-meter row of plants and c) 13 feet of row of plants. Arthropods collected by the D-Vac® sampler had similar relative variation values for the single-plant and 1-meter-row-of-plants sample unit sizes. Larger relative variation values resulted for D-Vac® sampling with a 13-foot-row-sample unit size. (The lower the relative variation the more acceptable the sampling technique). The estimate of the number per acre was consistently larger for the single-plant sample unit size. For visual whole plant sampling of boll weevils, Heliothis spp. larvae and eggs, and damaged fruit, the 1-meter-row-of-plants sample unit size yielded the lowest relative variation values. The D-Vac® sampling method was preferred over the sweep-net method for collecting cotton fleahoppers.

747. , and Sterling, W. L. 1974. Aggregation indices of cotton arthropods in Texas. Environ. Entomol. 3: 598-600.

Two indices were used to quantify the aggregation of cotton arthropods: the parameter K of the negative binomial distribution and Morisita's index of dispersion Iδ. Using frequency distribution data the average values of these indices were calculated. In general there was close agreement between K and Iδ. Cotton fleahopper, Pseudatomoscelis seriatus (Reuter), nymphs were more aggregated than fleahopper adults. A greater degree of aggregation was observed for boll weevil, Anthonomus grandis Boheman, eggs than for boll weevil adults. Bollworm, Heliothis zea (Boddie), and tobacco budworm, H. virescens (F.), eggs exhibited more aggregation than Heliothis spp. larvae. Aggregation continued to decrease as the Heliothis spp. larvae became full grown. Among the predatory cotton arthropods, lady beetles and minute flower bugs, Orius spp., displayed the greatest amount of aggregation. Big-eyed bugs, Geocoris spp., were less aggregated and the spatial distributions of spiders were the least aggregated of the predatory arthropods.

748. , and Sterling, W. L. 1975. Sequential sampling cotton squares damaged by boll weevils or Heliothis spp. in the Coastal Bend of Texas. J. Econ. Entomol. 68: 543-545.

Sequential sampling plans based on the binomial distribution were developed for sampling squares (floral buds) damaged by the boll weevil, Anthonomus grandis Boheman, or the bollworm, Heliothis zea (Boddie), and the budworm, H. virescens (F.). These plans were compared to a fixed-sample-size (100 squares) method of sampling damaged squares. Field trials indicated that the use of sequential sampling plans provided ca. 50% savings in time over the fixed-sample-size method. The treatment decisions were similar for both methods.

749. , and Urban, T. C. 1977. Dispersal of the boll weevil in the Coastal Bend area of Texas. Southwest. Entomol. 2: 4-7.

Leggett traps baited with Grandlure® were placed on the mainland, Padre Island and on unmanned oil platforms in the Gulf of Mexico. Numerous boll weevils were captured in the mainland traps, relatively few boll weevils were captured in the traps located on Padre Island and no boll weevils were captured in traps located in the Gulf of Mexico.

750. Pruitt, G. R.; Rummel, D. R.; Wade, L. J.; and White, J. R. 1978. Effects of a long-term suppression program on boll weevil susceptibility to malathion. Southwest. Entomol. 3: 215-218.

Laboratory studies of boll weevils, Anthonomus grandis Boheman, from the Texas High Plains suppression area were made to determine if any changes in susceptibility to malathion occurred during a 5-year period. LD_{50} and LD_{90} values for malathion treatments of these weevils were compared with those of a strain from an adjacent untreated area. No obvious changes in susceptibility were noted among any of the strains.

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751. Rainwater, C. F. 1970. Prospects for the eradication of the boll weevil. J. Wash. Acad. Sci. 60: 48-53.

A large-scale pilot experiment to provide technology for eradication of the boll weevil is described. A 10,000 acre cotton-growing area in southern Mississippi will be isolated and used for the integrated application of four previously tested control methods.

752. Reeves, B. G.; Wilkes, L. H.; Ridgway, R. L.; and Lindquist, D. A. 1967. Applying systemic insecticides to cotton: an equipment evaluation. Agric. Eng. 48: 646-647.

Laboratory studies indicate that applying certain systemic insecticides to the stem of cotton plants rather than to the soil gives up to 74 percent greater efficiencies. Stem treatments with systemic insecticides indicate good control of aphids, spider mites, cotton fleahoppers, lygus bugs, boll weevils, bollworms, and tobacco budworms. Large-scale field trials, however, have been infrequent because of a scarcity of mechanized equipment. In 1964, we built an experimental applicator that has two wood discs 6-in. in diameter and 1 1/2 in. thick. Discs, covered with sponge rubber, reached both sides of the cotton row. Rotating in a horizontal plane near the ground, these discs transferred the insecticide to the plant stems. In 1965 a more detailed research project was conducted to evaluate rotary and stationary brushes and lateral spray in the application of systemic insecticide to the main plant stems. In these further field tests the rotary brush applicator demonstrated effective control of cotton fleahoppers and lygus bugs. This method of application greatly reduces the hazards of drift and atmospheric contamination; its application efficiency is significantly above levels obtained with conventional methods of systemic insecticide applications.

753. Reiman, J. G., and Flint, H. M. 1967. Irradiation effects on midguts and testes of the adult boll weevil, Anthonomus grandis, determined by histological and shielding studies. Ann. Entomol. Soc. Am. 60: 298-308.

Histological studies demonstrated that radiation doses considerably below those required for sterilization killed most regenerative cells of boll weevils, Anthonomus grandis Boheman, which resulted in the loss of most or all of the secretory epithelium. Extensive damage to midgut was noted in 1 specimen that received 2000 R and in all those given 4000 R. Shielding experiments showed that when only the head and that part of the thorax anterior to the midgut

were irradiated, mortality did not exceed that of the control. Irradiation over the abdomen and the posterior part of the thorax produced the same level of mortality as did whole-body irradiation. These findings indicate that damage to the midgut is the basic cause of the high mortality among weevils given sterilizing doses of radiation. At 10 days after irradiation, no spermatogonia were found in any testes irradiated with 6000 R or more, and none were found in some testes that received only 2000 R.

754. Reinecke, L. H.; Klassen, W.; and Norland, J. F. 1969. Damage to testes and recovery of fertility in boll weevils fed chemosterilants. Ann. Entomol. Soc. Am. 62: 511-525.

Studies of mating and histology were made to test the fertility and spermatogenic activity of male Anthonomus grandis Boheman (Coleoptera: Curculionidae) several weeks after the weevils were fed the following chemosterilants: apholate; busulfan (1, 4-butanediol dimethanesulfonate); 1-aziridinylphosphonic acid cyclic diester with pentaerythritol; D-mannitol 1, 6-dimethanesulfonate; N, N, N', N'-tetramethyl-P-piperidinophosphonic diamide; and N, N, N', N'-tetramethyl-P-morpholinophosphonic diamide with and without 2 krad of X-rays. Damage to the spermatogenic cycle and the histopathology of testes from treated weevils are described. All chemical treatments at 1 of the concentrations used caused permanent damage to the testes of some weevils as evidenced by the death of all spermatogonia. However, none of the treatments caused permanent damage to all the testes at the concentrations used. Damage to the midgut occurred with some chemosterilants. Remating studies showed that recovery of fertility could occur after 4 weeks with 5 chemosterilants, although the data for D-mannitol 1, 6-dimethanesulfonate were insufficient for a firm conclusion.

755. Ridgway, R. L. 1967. Research on systemic insecticides and methods of applying them for control of cotton insects. Cotton Grow. Rev. 44: 39-50.

Seven systemic insecticides are currently being used for cotton 'nsect control in the United States. However, only two of them, disulfoton and phorate, are being applied so that true systemic action occurs; these two materials are applied as in-furrow and seed treatments and occasionally as sidedress treatments, primarily for the control of thrips, aphid and mites. Of a number of experimental compounds being evaluated for control of cotton insects, a new carbamate compound, Temik, appears to be of particular interest. Temik shows considerable promise for control of thrips, aphid, spider mites, cotton fleahopper, lygus bugs, and possibly boll weevil when it is applied as an in-furrow or sidedress soil treatment. The recently developed technique of stem treatment is a method of applying systemic insecticides efficiently in spite of soil and moisture conditions that are unfavorable for sidedress soil treatments. Stem treatments of systemic insecticides have been used to control aphids, spider mites, cotton fleahopper, and lygus bugs in field experiments.

756. . 1970. Improved use of insecticides on cotton and some alternate methods of insect control. Proc. Annu. Tex. Conf. Insect Plant Dis. Weed Brush Control, 3: 204-207, Dec., 1970. Texas A&M University, College Station, Texas.

Considerable evidence is available to indicated that insecticides can be utilized more effectively and that biological agents can be used to control insect pests. Additional research on formulations and selective insecticides and the development and/or implementation of management techniques satisfactory for implementing more desirable use patterns should result in more desirable uses of insecticides.

Similarly, wide spread practical use of biological control agents will require the development of predictable and economical methods of mass production and distribution of these agents as well as the development of management systems in which these more sophisticated control methods can be utilized economically.

757. . 1970. Systemics and their use in cotton production. Proc. Annu. Tex. Conf. Insect, Plant Dis. Weed Brush Control, 2: 233-234, Feb., 1970, Texas A&M University, College Station, Texas.

Although systemic insecticides are available that will provide effective control of many of the pests on cotton, it is important that their use be planned after considering the entire cotton insect complex. For instance, the bollworm and tobacco budworm are becoming increasingly difficult to control. Since systemic insecticides may increase bollworm and budworm populations due to destruction of beneficial insects and their food, the advantages and possible disadvantages of applying systemic insecticides should be carefully evaluated before they are used.

758. . 1971. Aldicarb (Temik) for control of cotton insects. Summary Proc. 1971 West. Cotton Prod. Conf. pp. 17-18.

Aldicarb, an effective new tool for controlling cotton pests, is now available for use by cotton producers. Like all other production tools, it has its advantages and disadvantages including the economics involved before making decisions on when and where it should be used.

759. . 1973. Integrated control of cotton insects in the United States. Proceed. 31st Plen Meet. of Int. Cotton Advis. Com. pp. 190-195.

Cotton is grown on about 11 million acres throughout the southern United States. The principal injurious insects include the boll weevil, Anthonomus grandis Boheman; the bollworm, Heliothis zea (Boddie); the tobacco budworm, H. virescens (F.); the pink bollworm, Pectinophora gossypii Glover;

the cotton fleahopper, Pseudatomoscelis seriatus (Reuter); and lygus bugs, Lygus hesperus Knight and L. lineolaris (P. de B.). A number of other insects (and spider mites) occasionally cause serious damage. Practical techniques by producers, research continues to develop even more desirable methods of insect control. In addition to research on new insecticides, major research efforts are in progress on cultural controls, resistant and/or determinant varieties, hormones, pheromones, insect sterility, and biological control using parasites, predators, and pathogens.

760. . 1976. Recent advances in boll weevil research. Proc. 1976 Beltwide Cotton Prod.-Mech. Conf., pp. 46-47.

As a prelude to my comments on recent advances in boll weevil research, perhaps I should review some of the significant events that have influenced the completion of the pilot experiment in the fall of 1973 the technical guidance committee for the experiment concluded that it was technically and operaionally feasible to eliminate the boll weevil as an economic pest from the United States by means which were economically sound. However, the committee also emphasized the need for additional research to refine technology and reduce costs. Likewise, an evaluation committee appointed by the Entomological Society of America expressed reservations as to whether the pilot trial actually demonstrated the capability for eradicating the boll weevil and suggested the need for additional research to improve mass production, sterilization, and the use of the boll weevil pheromone, grandlure. The need to determine the relative value of the various components of a proposed eradicated system was also stressed. In view of the various uncertainties which arose, a meeting of most interested parties was held in Memphis in the fall of 1974. At this meeting, agreement was reached that a three-year tiral eradication program should be undertaken in Virginia, North Carolina and South Carolina and that future action should be based on the results of this trial. In the meantime, the Agricultural Research Service redirected some on-going research

to place additional emphasis on those areas where the pilot experiment identified a particular need for research. Significant research progress has been made during the past two years in a number of areas. I will comment on progress in four areas: mass rearing, sterilization, pheromones, and an insect growth regulator.

761. . 1977. Future outlook for chemical and biological control of cotton insects. Summary Proc. 1977 West. Cotton Prod. Conf., pp: 68-69.

There is a wide range of chemical and biological methods which are potentially useful in the control of cotton insects. Although there are different approaches to classification of these methods, the chemical methods might include (1) insecticides, (2) insect growth regulators, (3) behavior chemicals, (4) plant growth regulators, and (5) harvest aid chemicals, whereas the biological methods might include (1) parasites and predators, (2) pathogens, (3) autocidal control, (4) host plant resistance, (5) rapid fruiting varieties, and (6) cultural practices. However, in order to effectively utilize one or more of these methods, a number of management techniques should be utilized. These techniques are sometimes referred to collectively as "decision-making technology." For the purpose of looking at the immediate future, with particular reference to western cotton production, I will concentrate on five topics, namely, insecticides, behavior chemicals, host plant resistance, genetical control, and decision-making technology. Some very important work with plant growth regulators will be discussed later this morning by another speaker. Also, since we are looking at cotton insects primarily as they affect western cotton production, the insects of most concern are pink bollworm, lygus bugs, bollworm/tobacco budworm, and spider mites. In order to relate my comments to current practices, perhaps it would be helpful to briefly review insect control costs in the western cotton growing areas. As most of you know, cotton insects are not a major problem on the High Plains of Texas, and, consequently, insect control costs are minimal. However, we also recognize the importance of continuing actions to prevent esta-

blishment of the boll weevil in the High Plains. Conversely, the Imperial Valley of California, primarily because of the pink bollworm, is the highest insect control cost area in the U.S. Control costs in the San Joaquin Valley are substantial, but somewhat less than other areas in California and Arizona. But, if the pink bollworm becomes a major pest in the San Joaquin Valley, insect control costs in that area could increase greatly.

762. . 1978. Insect control becoming more difficult. Cotton Int. 1978 Ed. 76-77.

Control of cotton insects in the United States is becoming more difficult because of (1) the increasing development of insecticide resistance, (2) the decreasing availability of insecticides, and (3) the rapidly increasing costs of insecticides and their application. Fortunately, research is providing a number of innovations that should be useful in the management of cotton insects. Advances are being made in the development of such suppression methods as resistant and short-season varieties, cultural methods, biological agents (parasites, predators, and microbial agents), genetic manipulation, specialty chemicals (growth regulators, pheromones, and other behavior chemicals), and insecticides. However, effective and economical cotton insect control will require intensive management of various insect suppression methods as an integral part of a total cotton production system.

763. . 1978. Status of the boll weevil eradication and optimum pest management trials. Proc. 1978 Beltwide Cotton Prod. Res. Conf., pp. 108-109.

In my view, the boll weevil eradication trial and optimum pest management demonstration, which will be conducted furing the next 3 years, together with the comprehensive evaluation, offer the potential for obtaining a vast amount of information that can be invaluable in determining the future direction of cotton insect management in the U.S. However, for this potential to be realized, continued cooperation and dedication of all interested parties is essential. So, let us move ahead together.

764. ; Bariola, L. A.; and Hardee, D. D. 1971. Seasonal movement of boll weevils near the High Plains of Texas. J. Econ. Entomol. 64: 14-19.

Field inspections and wing traps containing live male Anthonomus grandis Boheman were used in 1968 to study the seasonal movement of boll weevils near the High Plains of Texas. Peak populations of overwintered weevils occurred in cotton fields within 4-5 weeks after planting. Movement of boll weevils began early in the spring before cotton was planted, decreased greatly during midsummer, and increased again to a very high level late in August. Relatively large numbers of weevils were captured in both the spring and fall at distances more than 6 miles from cotton.

765. ; Gorzycki, L. J.; and Lindquist, D. A. 1966. Effect of metabolite analogs on larval development and oviposition in the boll weevil. J. Econ. Entomol. 59: 143-146.

Eighteen compounds were evaluated for their effects on larval development of oviposition or both in the boll weevil, Anthonomus grandis Boheman. Methotrexate, 5-fluoroorotic acid, and 5-fluorouracil were among the most active compounds tested. The addition of uracil and ribonucleic acid to adult diets containing 5-fluoroorotic acid and 5-fluorouracil partially reversed their effect on oviposition.

766. ; Hollingsworth, J. P.; and Bull, D. L. 1976. Efficiency of boll weevil pheromone traps. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8: 16-19.

A boll weevil trapping device using a natural or synthetic chemical as an attractant is commonly called a boll weevil pheromone trap. Grandlure, the chemical that approximates the natural attractant of the boll weevil, is widely used in the boll weevil pheromone trap. Although the most effective

use of this trap involves complex variables related to environmental, physiological, chemical, and physical factors, reliable quantitative estimates of trapping efficiency (the percent of a population caught by a trap or a group of traps) are essential to their successful use for either survey or suppression. Results of limited studies to date are inconclusive and indicate efficiencies ranging from 12 to 93 percent, but the available information indicated that the density of the natural boll weevil population is probably the most critical factor affecting trap efficiency and that trap efficiency is highest when densities are lowest. Thus, the present pheromone traps show promise of suppressing populations when native populations are low, probably 10 or less per acre.

767. ; Jones, S. L.; Coppedge, J. R.; and Lindquist, D. A. 1968. Systemic activity of 2-methyl-2-(methylthio)propionaldehyde O-(methyl-carbamoyl)oxime (UC-21149) in the cotton plant with special reference to the boll weevil. J. Econ. Entomol. 61: 1703-1712.

Bioassay of parts of cotton plants that had been sidedressed with 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime (Union Carbide UC-21149) showed that the greatest amount of toxicant accumulated in older leaves and the least in debracted squares (floral buds). One sidedress application of 4 lb toxicant per acre or 2 sidedress applications of 2 lb per acre effectively controlled Anthonomus grandis Boheman, in field cages; however, 2 applications were more effective. When the same total amounts of UC-21149 were applied as multiple and single sidedressings, the multiple applications resulted in greatest uptake in new plant growth. Both deep placement in the soil close to the cotton plant and irrigation increased the uptake of sidedressed UC-21149, but placement did not affect uptake when the soil was irrigated. Foliar applications of a cottonseed oil feeding stimulant increased the effectiveness of a sidedressing of UC-21149. After soil appli-

cations, the S^{35}-labeled sulfoxide of UC-21149 [2-methyl-2-(methylsulfinyl) propionaldehyde O-(methylcarbamoyl) oxime] was the major toxic component of squares. After stem applications 8.6-24.2% of the radiolabeled compound was recovered in the plant above the point of treatment.

768. ; Jones, S. L.; and Gorzycki, L. J. 1966. Tests for boll weevil control with a systemic insecticide and a boll weevil feeding stimulant. J. Econ. Entomol. 59: 149-153.

The use of a systemic insecticide, American Cyanamid CL-47031 (cyclic ethylene (Diethoxyphosphinyl) dithioimidocarbonate), with a feeding stimulant to control the boll weevil, Anthonomus grandis Boheman, was explored. Laboratory tests indicated that the treatment of leaves with a feeding stimulant formulated with sucrose and agar altered both the feeding behavior and movement of boll weevils. CL-47031 applied in a granular formulation as a soil treatment and in a lanolin paste as a stem treatment to cotton just beginning to fruit gave substantial mortalities of adult boll weevils. When CL-47031 was applied as a stem treatment to fruiting cotton and a boll weevil feeding stimulant, a water extract of squares (3g/10 ml water), formulated with sucrose and agar was applied as a foliar spray, weevil mortality was more than twice that obtained when the same insecticide was used alone.

769. , and Lindquist, D. A. 1966. Systemic activity of Shell SD-9129 in cotton plants. J. Econ. Entomol. 59: 961-964.

The systemic activity of Shell SD-9129 (dimethyl phosphate ester with 3-hydroxy-N-methyl-cis-crotonamide) in cotton plants was studied by bioassay and radioassay. The insects and a mite used for bioassay were the cotton aphid, Aphis gossypii Glover; the boll weevil, Anthonomus grandis Boheman; and the carmine spider mite, Tetranychus telarius (L.). After application

to lower leaves, little or no SD-9129 was found in untreated leaves above treated lower leaves. However, relatively large amounts were found in nectar of the cotton plant after the toxicant was applied to the stem. SD-9129 was not particularly effective as a systemic insecticide when it was applied to cotton seed or to the soil.

770. ; Walker, H. J.; Hanna, R. L.; and Owen, W. L. 1967. Fertilizers impregnated with systemic insecticides for control of cotton insects. J. Econ. Entomol. 60: 592-594.

Greenhouse and field tests were conducted to compare the effectiveness against cotton insects of granules and fertilizer impregnated with phorate, disulfoton, and American Cyanamid CL-47031 (cyclic ethylene (diethoxphosphinyl)dithioimidocarbonate) and applied to cotton plants. Bioassays and radioassays of treated plants indicated that the levels of uptake from both formulations were similar after in-furrow and sidedress applications. Phorate and disulfoton were stable on 1 grade of fertilizer for more than 3 months.

771. Roach, S. H. 1973. Developmental changes in the boll weevil, Anthonomus grandis, studied with time-lapse photography. Ann. Entomol. Soc. Am. 66: 24-27.

Time-lapse photography techniques were developed to determine the time required for Anthonomus grandis Boheman, held at 26.6°C, to change from each developmental stage to the next. The mature embryo abraded the egg chorion in 2-4 minutes. The time required from the initial splitting of the cuticle of 2nd- and 3rd-stage larvae to complete cast off of the cuticle was also 2-4 minutes. Durations of the stages were: 2-3 days for the egg; 1-2 days for the larval stadium; 1-15 days for the 2nd stadium; 4-7 days for the 3rd stadium including prepupa; and 4 days for pupa.

772. . 1979. Boll weevils: reproductive potential, feeding, and longevity of overwintering adults, and some effects of photoperiod on fecundity. J. Ga. Entomol. Soc. 14: 346-350.

Boll weevils, Anthonomus grandis grandis Boheman, taken from woods trash were held singly, paired, and one female with two males on cotton squares. Females held singly laid fertile eggs, but with males the number and viability of eggs, % females laying eggs, and oviposition were significantly increased. Time or longevity of weevils, In addition, females held in a 10-h day-length were significantly less reproductive than females held in a 14-h day-length, and females were found to continue oviposition during both the light and dark periods.

773. ; Agee, H. R.; and Ray, L. 1972. Influence of position and color of male-baited traps on captures of boll weevils. Environ. Entomol. 1: 530-532.

Three colors of plastic boll weevil pheromone traps were compared for capture of boll weevils. In addition, the location of the traps around cotton fields and proximity to overwintering sites as related to trap capture was evaluated. In these tests, location of the traps was more important in weevil capture than the color of the traps.

774. , and Leggett, J. E. 1979. Boll weevil parasites: emergence from cotton squares in the Florence, S.C. area. J. Econ. Entomol. 72:162-164.

From June to Oct. in 1974, 1975, and 1976, field collections were made of fallen and flared cotton squares punctured by boll weevils, Anthonomus grandis grandis Boheman. These squares were held in an insectary and observed for emerging boll weevils and larval parasites. In addition, adult boll weevils that survived the winter were observed for parasites in 1975. Four species of hymenopteran parasites were recovered; also 2 dipteran species were found when adult boll weevils were dissected.

775. , and Ray, L. 1971. Boll weevils captured at Socastee, South Carolina, in 1970, in wing traps placed around fields with and without growing cotton. J. Econ. Entomol. 64: 559-560.

When wing traps were placed around isolated fields with and without growing cotton the numbers of Anthonomus grandis Boheman that were captured were correlated with the traps at both fields regardless of the presence of cotton. The numbers of weevils observed in the cotton field were not correlated with the numbers of weevils captured on the traps.

776. ; Ray, L.; Hopkins, A. R.; and Taft, H. M. 1971. Comparison of attraction of wing traps and cotton trap plots baited with male boll weevils for overwintered weevils. Ann. Entomol. Soc. Am. 64: 530.

Small plots of cotton containing male boll weevils were compared with wing traps containing male boll weevils for early season attraction to overwintering boll weevils. In general the cotton plots were difficult to establish and much less attractive to boll weevils than the wing traps.

777. ; Ray, L.; Taft, H. M.; and Hopkins, A. R. 1971. Wing traps baited with male boll weevils for determining spring emergence of overwintered weevils and subsequent infestations in cotton. J. Econ. Entomol. 64: 107-110.

When wing traps baited with male Anthonomus grandis Boheman were placed around small cotton fields in a ratio of 1 trap per 2 to 3 acres, a positive correlation was found between the number of overwintered weevils captured and the number observed in the field. However, the estimate obtained by sampling the number of weevils hibernating in woods trash did not correlate with the number captured or observed. The location of traps in relation to overwintering sites influenced the captures on the traps, and time of entry of weevils into the fields appeared to be related to the beginning of fruiting by the cotton.

778. ; Taft, H. M.; Ray, L.; and Hopkins, A. R. 1971. Population dynamics of the boll weevil in an isolated cotton field in South Carolina. Ann. Entomol. Soc. Am. 64: 394-399.

In 1968 and 1969, the rate of increase of a population of Anthonomus grandis Boheman was observed in a small cotton field isolated from other cotton plantings by distances of 14-26 miles. Wing traps baited with unmated male boll weevils were used to study the size of the population and the movement of weevils in the area around the field. In both years, the population increased to destructive levels within the period of F_1 adult emergence, and 80-90% of all developing cotton fruiting structures were continually destroyed when the population was 2000 or more per acre. The wing traps captured 85% of the emerging overwintered weevils but were ineffective in controlling later generation weevils. Traps placed away from the field revealed extensive immigration of F_1, F_2, and F_3 weevils into the area, apparently from distant cotton fields.

779. , and Walker, J. T. 1970. A parasitic mite found on boll weevils near Florence, South Carolina, in 1968. J. Econ. Entomol. 63: 646-647.

Overwintered boll weevils captured in pheromone traps were parasitized by larval mites (Leptus spp.). Up to 50% of collected weevils had mites attached. No measures were made of the debiliting effects of the mites on the weevils.

780. Robertson, O. T.; Noble, L. W.; and Orr, G. E. 1966. Spread of boll weevils and its control in far west Texas. J. Econ. Entomol. 59: 754-756.

The boll weevil, Anthonomus grandis Boheman, became established in the Presidio Valley of Texas in the early 1950's. Robertson reporting on the infestation through 1955, showed that the insect first became established in the eastern end of the valley and moved northward to Candelaria. The western boundary of the infestation in 1955 was about 75 miles below the El Paso Valley, which comprises a strip of irrigable land along the Rio Grande in Hudspeth and El Paso

(page 399 follows)

782. Roth, H., and Kennedy, J. W. 1972. Methyl bromide and aluminum phosphide as fumigants for control of adult boll weevils: laboratory studies. J. Econ. Entomol. 65: 1650-1651.

Adults (2-4 days old) of a laboratory-reared strain, Ebony Pearl, Anthonomus grandis Boheman were readily controlled with methyl bromide (MeBr) or aluminum phosphide. At temperatures below 10°C, much higher concentration-time produces (CT) of MeBr were apparently required for control than expected if the relationship between CT and temperature were a straight line. There was some indication that adults 9-11 days old were more tolerant to aluminum phosphide than 2- to 4-day-old adults. Fumigation schedules are recommended for quarantine control.

783. Roussel, J. S. 1976. In-season control of the boll weevil. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 26-27.

In-season control of the boll weevil is an essential element in any program of boll weevil control and elimination. To be successful, it will have to be performed in a thorough manner, with every producer and every field included. We already have the knowledge and methodology to suppress the weevil to an extremely low population level in preparation for a diapause program. Because a united effort is so important, leadership of the cotton industry must produce incentives which will assure the effective participation of every cotton producer in the Cotton Belt. Lack of cooperation on the part of any single producer will be critical in the ultimate success of the program.

784. Ruesink, W. G. 1976. Status of the systems approach to pest management. Annu. Rev. Entomol. 21: 27-44.

Systems science has only recently been applied to pest management. The development of a sound pest-management strategy depends on our ability to understand all the significant and relevant interactions of the real world. Models serve as a crutch to aid our mental recall. The method of design is to manipulate our concept of the real world (our model) using potentially useful tactics in all possible combinations. Then the combination must be evaluated so the best one may be chosen.

785. Rukavishnikav, B. I. 1968. Genetic methods of insect control. Genetika 4: 796-811.

Problems of irradiation and chemical sterilization of insect pests, including the boll weevil, breeding of genetically inferior races of insects and their release in natural populations are discussed in the article.

786. Rummel, D. R. 1967. Preliminary report High Plains boll weevil survey-1966. Tex. Agric. Exp. Stn. Dep. Entomol. Tech. Rep. 5, 16 pp.

An intensive boll weevil survey was conducted in the High Plains boll weevil control zone during the summer of 1966. Survey data indicates that emerging overwintered boll weevil populations were very small following the 1965 diapause boll weevil control program. Only 11 overwintered adults were detected in the eight-county control zone by July 15 when first generation weevils began to emerge. Overwintered populations were centered primarily in the heavy shinnery oak areas of Dickens and Kent counties. In the control zone area above the Caprock, only two overwintered adults were detected. Economic infestations failed to develop above the Caprock during the growing season. Populations developed slowly during the summer with irrigated cotton producing the largest infestations. Only 15,712 acres were known to be infested

by September 1. This represented only 19 percent of the surveyed area. An average of 58 adult weevils per acre was reached by September 1 when the survey was completed.

787. . 1968. Size and rate of diapause increase of boll weevil populations in Kent and Dickens Counties in 1967. Tex. Agric. Exp. Stn. Dep. Entomol. Tech. Rep. 15, 13 pp.

Boll weevil population studies were conducted in 62 fields in Kent and Dickens Counties during the summer of 1967. Survey data indicated that overwintered weevil populations were very small and localized. Weevil populations in the surveyed fields showed a smaller rate of increase between the first and third generations than in 1966, however, the population in 1967 developed to a greater size than in 1966. Also, infestations were detected in a greater percentage of surveyed fields than in 1966. Infestations generally remained at sub-economic levels during the survey period.

788. . 1976. An area-wide boll weevil suppression program-organization, operation and economic impact. Tex. Agric. Exp. Stn. Misc. Publ. MP-1276, pp. 152-159.

Each year since 1964, a suppression program has been directed against the boll weevil, Anthonomus grandis Boheman, population along the juncture of the Texas High and Rolling Plains. The suppression effort has successfully prevented the westward spread of the pest into the more than 2 million acres of High Plains cotton. This program represents the largest coordinated effort ever undertaken to combat a cotton pest. It also serves as an excellent example of cooperation among state and federal agencies and producers.

789. . 1976. Reproduction-diapause boll weevil control. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 28-30.

It is a mistake to consider reproduction-diapause control only as a major component of an eradication program. In areas where successfully tested, this control method can be considered a true pest management technique. A combination of reproduction-diapause or diapause control with certain cultural practices, such as delayed uniform planting dates, application of harvest-aid chemicals, and early harvest and stalk destruction, will produce a highly effective and economical pest-management system for many areas. There is considerable promise for developing effective boll weevil management programs based upon the late-season suppression of potential overwintering weevils in combination with short-season cotton, resistant varieties, and pheromone trapping systems.

790. . 1980. Effectiveness of diflubenzuron (Dimilin) for boll weevil suppression in Texas. Southwest. Entomol. (Preface.) Suppl. 1: 1.

Herein, we review research conducted in Texas on the mode of action and environmental fate of diflubenzuron and on its use in the suppression of boll weevil populations. The IGR was tested at various rates and with different application techniques in several cotton producing areas of the state. Diflubenzuron was compared to conventional insecticides for effectiveness in weevil suppression and for detrimental effects on beneficial arthropods. The fate of the IGR after application to boll weevils, plants, and soil are discussed and suggestions for its use in boll weevil control are offered.

791. . 1980. Effectiveness of diflubenzuron (Dimilin) for boll weevil suppression in Texas. Southwest. Entomol. Suppl. (Summary) 1: 36-37.

The results reported in this study suggest that adequate season-long control of boll weevils with diflubenzuron, even with light to moderate infestations, will be difficult and may require special management practices. The most effective method of using diflubenzuron for boll weevil control appears to be a program designed to suppress reproduction by overwintered females. Due to the mode of action of diflubenzuron (i.e., inhibited reproduction) and the boll weevil's capacity for rapid population increase, the 1st application must be made to cotton when fruiting is in the "pinhead square" stage or earlier, before oviposition begins. The unusual persistence of diflubenzuron on cotton does not result in extended activity against the boll weevil, and it apparently must be applied at regular intervals of 5-7 days for an extended period to maintain control. This type program would be designed to limit boll weevil reproduction long enough to obtain an acceptable boll set before the populations develop to a damaging level after the termination of treatments. In instances where the overwintered boll weevil population is large, diflubenzuron applications may have to be supplemented with fall treatments for diapausing weevils and/or with at least 1 application of a conventional insecticide in the spring to reduce the number of adult boll weevils that survive the winter. Diflubenzuron applications should be integrated with proven management practices such as planting short season cotton varieties and early harvest and stalk destruction. In addition, the use of the IGR in community or area-wide programs would produce better results than when used on an individual farm basis. Research conducted in Texas indicates that diflubenzuron does have a place in boll weevil management. However, both the advantages and disadvantages related to its use must be considered.

792. . 1980. Effectiveness of diflubenzuron on boll weevils in the Texas Rolling Plains. Southwest. Entomol. Suppl. 1: 8-14.

Under conditions of heavy boll weevil infestation 8 applications of diflubenzuron at rates of 35, 70 and 140 g AI/ha resulted in a seasonal average adult boll weevil, Anthonomus grandis Boheman, emergence of 44.4, 40.0, and 27.0%, respectively. Adult boll weevil emergence from untreated cotton plots averaged 73.5%. Lint yield data indicated the 70 and 140 g AI/ha rates to be equal in effectiveness to 8 applications of azinphosmethyl at a rate of 336 g AI/ha. Four applications of diflubenzuron at rates of 52.5, 70, and 140 g AI/ha directed against a light overwintered boll weevil population resulted in adult emergence of 24.5, 13.4 and 9.7%, respectively. All rates of diflubenzuron were less detrimental to selected beneficial arthropods than azinphosmethyl.

793. , and Adkisson, P. L. 1970. Distribution of boll weevil-infested cotton fields in relation to overwintering habitats in the High and Rolling Plains of Texas. J. Econ. Entomol. 63: 1906-1909.

In 1966, cotton fields infested with Anthonomus grandis Boheman in an 8-county area of the High and Rolling Plains of Texas were distributed in a nonrandom, "clumped" pattern following an areawide reproductive-diapause control program in 1965. During a period of low weevil density, the distribution of cotton fields infested with weevils appeared to be influenced primarily by the abundance of favorable weevil overwintering habitats within the cotton growing area, and by the distance of the habitats from the cotton fields. Most of the infested fields were immediately adjacent to a favorable boll weevil overwintering habitat. Infestations were detected in very few fields situated more than 1/2 mile from overwintering habitats, with more than 50% of the infested fields situated within 1/2 mile of heavy shinnery oak or mesquite stands.

794. , and Adkisson, P. L. 1971. A two-phased control program designed for maximum suppression of the boll weevil in the High and Rolling Plains of Texas. J. Econ. Entomol. 64: 919-922.

A hypothetical model of a 2-phase or reproductive-diapause control program for Anthonomus grandis Boheman is presented. The proposed program is designed for maximum suppression of the boll weevil population in the High and Rolling Plains area of Texas. The proposed program represents a modification of current 2-phase programs by employing an earlier starting date, based upon the ecology of the weevil in the Texas High and Rolling Plains. It is suggested that this type program will be the necessary 1st phase of any future boll weevil eradication effort.

795. , and Bottrell, D. G. 1976. Relationship of overwintered boll weevil response to pheromone traps and natural entry into cotton. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 26-31.

Investigations of boll weevil, Anthonomus grandis Boheman, response to pheromone traps and trap crops were conducted in the Rolling Plains of Texas during the period 1969-74. Both laboratory reared male weevils and the synthetic pheromone grandlure were used as pheromone sources in the tests. Weevil response patterns were similar regardless of the location of the pheromone source in relation to cotton. The seasonal decline in weevil response began at about the same time when the pheromone source was located adjacent to cotton, in cotton, or several miles from cotton. Overwintered boll weevil activity measured by pheromone traps and by actual entry of adult weevils into isolated cotton plots showed different trends. Peak overwintered weevil movement into cotton occurred 1 month after the peak period of weevil response to traps. Therefore, pheromone trap catches in the spring do not appear to provide an entirely accurate measure of overwintered

weevil movement into cotton. Results of this study suggest that weevil response to grandlure is a seasonally related phenomenon, not greatly influenced by competition from pheromone-producing male weevils in cotton.

796. , and Bottrell, D. G. 1976. Seasonally related decline in response of boll weevils to pheromone traps during mid-season. Environ. Entomol. 5: 783-787.

The seasonal response of Anthonomus grandis Boheman to pheromone produced by males of the species and the synthetic pheromone (grandlure) was investigated in the Rolling Plains of Texas over a 6-yr period. Records were maintained on numbers of boll weevils captured on traps located at various distances from cotton fields. Weevil entry into grandlure-baited cotton was compared to weevil response to traps. The last major period of overwintered weevil response to the pheromone source during the spring and a subsequent decline in response occurred about the same time during most years independent of the pheromone location with respect to cotton. The similarity in weevil response trends indicated that the presence of pheromone producing ♂ weevils in cotton was not a major causal factor in the decline in weevil response to traps. These results contradict an earlier hypothesis stating that reduced response to traps during mid-season is initiated by competition from ♂ weevils inhabiting cotton in the trapping area. The present study concludes that the decline in weevil response to traps in the spring is a seasonally related phenomenon regulated by presently unknown factors but not by competition from pheromone-producing weevils in cotton.

797. ; Bottrell, D. G.; Adkisson, P. L.; and McIntyre, R. C. 1975. An appraisal of a 10-year effort to prevent western spread of the boll weevil. Bull. Entomol. Soc. Am. 21: 6-11.

Each year since 1964 a boll weevil, Anthonomus grandis Boheman, population

suppression program has been conducted along the juncture of the Texas High and Rolling Plains. The suppression effort is designed to prevent the westward spread of the insect into the more than 2 million acres of High Plains cotton, and possibly into New Mexico. This program represents the largest coordinated program ever undertaken to combat a cotton pest. It also serves as an excellent example of cooperation among state and federal agencies and producers. The present paper presents an appraisal of the effectiveness of the suppression effort after 10 years of operation.

798. , and Frisbie, R. E. 1978. Suppression of potentially overwintering boll weevils as a pest management practice. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 39-49.

The suppression of prehibernating boll weevils during late season has proved to be a highly effective weevil suppression technique in most areas where it has been adequately tested. This technique offers numerous advantages over previous chemical control programs, including 1) more effective control, 2) greatly reduced costs as a result of elimination of or significant reduction in requirements for in-season insecticide applications, 3) reduced probability of outbreaks of Heliothis and other secondary pests as a result of reducing insecticide use during the growing season, and 4) less impact on beneficial arthropod populations. Although this suppression method has been shown to be effective in some areas of the Cotton Belt, it has gained only limited acceptance. Due to differences in ecological conditions the high level of suppression obtained in some Texas programs may not be possible in the more humid areas of the Cotton Belt. However, it is unfortunate that the fall suppression of prewintering boll weevils has not been more widely tested in areas where the boll weevil is a key pest. The high level of organization and cooperation required is the greatest disadvantage in application of this suppression technique. However, it has been demonstrated in several areas

that the necessary organization and cooperation can be achieved and an effective management program accomplished.

799. , and Jordan, L. B. 1973. A rescheduled reproductive-diapause control program for maximum suppression of potential overwintering boll weevils in the Rolling Plains of Texas. Tex. Agric. Exp. Stn. Prog. Rep. PR-3210, 1 p.

A reproductive-diapause control program utilizing a revised application schedule proposed by Rummel and Adkisson (1971) was tested in eight cotton fields in Dickens and Kent counties in 1972. Large numbers of newly emerged second and third generation boll weevils, Anthonomus grandis Boheman, were effectively controlled before oviposition occurred. Oviposition was greatly reduced during August and September by the revised control schedule. However, boll weevil migration from surrounding untreated fields caused continuous reinfestation of the treated fields. The insecticide leptophos provided satisfactory boll weevil control and also suppressed moderate bollworm, Heliothis zea (Boddie), populations.

800. ; Jordan, L. B.; White, J. R.; and Wade, L. J. 1977. Seasonal variation in the height of boll weevil flight. Environ. Entomol. 6: 673-678.

Pheromone traps placed at heights ranging from ground level-9.1 m were used to study boll weevil flight in the vicinity of an infested cotton field during 1972-73. A definite seasonal variation in the height of boll weevil flight was noted. During the spring, weevil flight from hibernation areas to cotton appeared to be confined mostly to low levels. Over 90% of the overwintered weevils were captured from ground level-4.6 m, with ca. 70-80% captured from ground level-1.1 m. This low-level flight appears to be correlated with relatively short-range movement by most overwintered weevils. During the late summer and

fall migratory period, a significant increase in the height of boll weevil flight was recorded. Weevil capture at the 9.1 m level increased ca. 10-fold in 1972 and 8-fold in 1973. Weevils were captured at altitudes up to 122 m with aircraft-towed nets during the fall of 1973. During late season, migrating weevils appeared to be distributed from near ground level up to relatively great heights. These data indicate that considerable numbers of weevils may be capable of the long-range movements reported from previous studies.

801. ; McIntyre, R. S.; and Neeb, C. W. 1976. Suppression of boll weevils with grandlure-baited trap crops. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 53-61.

Trap-crop systems employing early planted strips of cotton, grandlure, and insecticide were tested for effectiveness in suppressing boll weevil populations during the 1972-74 seasons. These tests were designed to develop and evaluate systems in which overwintered boll weevils are aggregated into a small portion of the field where they can be easily and economically controlled. Thus, if the system functions properly, the major portion of the cotton field will support a smaller weevil population than normal. Therefore, damage will remain below an economic level, or at least economic damage will occur significantly later than in the absence of a trap crop. Results of trap-crop tests reported here fail to show consistent clear-cut examples of effective weevil control. The greatest difficulty encountered in implementing trap-crop systems was that of obtaining trap-crop cotton which was significantly more advanced in growth than the regularly planted crop. Although some test indicated weevil suppression, the practicality of using trap crops in a weevil control system is questionable at this time.

802. ; Pruitt, G. R.; White, J. R.; and Wade, L. J. 1979. Comparative effectiveness of diflubenzuron and azinphosmethyl for control of boll weevils. Southwest. Entomol. 4: 315-320.

Eight applications of diflubenzuron at rates of 35, 70 and 140 g AI/ha resulted in a seasonal average adult boll weevil emergence of 44.4, 40.0, and 27.0 percent, respectively. Adult weevil emergence from untreated cotton check plots averaged 73.5 percent. Under conditions of heavy weevil infestation, lint yield data indicated the 70 and 140 g AI/ha rates to be equal in effectiveness to 8 applications of azinphosmethyl at a rate of 336 g AI/ha. All rates of diflubenzuron were less detrimental to selected beneficial arthropods than azinphosmethyl.

803. ; Sterling, W. L.; and Adkisson, P. L. 1967. Evaluation of the 1966 diapause boll weevil control program on the High Plains of Texas. Tex. Agric. Exp. Stn., Dep. Entomol., Tech. Rep. 8, 11 pp.

The third year of an insecticidal spray program aimed at reducing the diapausing boll weevil, Anthonomus grandis Boh., population in an eight county area of the High and Rolling Plains was completed November 4, 1966. Significant progress has been made in reducing the boll weevil population in the area. The potential overwintering population in the control zone in 1966 was estimated to be 96.7% smaller than in nearby untreated acreages. Recent examinations of leaf litter in locations known to be suitable for boll weevil hibernation indicated that the 1966-1967 overwintering population in the treated zone was extremely small. Records indicate that the potential overwintering population in February, 1967 was 42% smaller than in February, 1966.

804. ; Wade, L. J.; and White, J. R. 1977. Efficiency of grandlure baited boll weevil traps. Southwest. Entomol. 2: 137-143.

Estimates of the efficiency of grandlure baited traps in capturing boll weevils,

Anthonomus grandis Boheman, were made during the 1976 growing season. Marked, native boll weevils were released at regular intervals near traps located in cotton and in rangeland. The response of weevils to traps located in rangeland was relatively consistent throughout the test period with a mean seasonal recapture rate of 11.2 percent. The recovery rate of weevils released in cotton during the pre-square and early squaring period as 10.4 percent but trap efficiency averaged less than 3 percent during the mid and late season periods.

805. ; White, J. R.; Carroll, S. C.; and Pruitt, G. R. 1980. Pheromone trap index system for predicting need for overwintered boll weevil control. J. Econ. Entomol. 73: 806-810.

Studies were conducted during 1977-79 to determine if grandlure baited traps could be used to predict the need to treat for overwintered Anthonomus grandis grandis Boheman. A positive relationship was established between the mean number of overwintered weevils captured per trap per field just prior to the appearance of squares suitable for oviposition and the percent oviposition damaged squares during the early 1/3-grown square period. A trap index threshold was developed and applied to actual field situations. The accuracy of the trap index system in determining the need for overwintered boll weevil control was compared to conventional field sampling. The trap index method was more accurate than field scouting in providing a warning of overwintered weevil infestation before squares of a suitable size for oviposition were present. They system was equally effective in indicating when overwintered weevil control was unnecessary.

806. ; White, J. R.; and Pruitt, G. R. 1978. A wild feeding host of the boll weevil in west Texas. Southwest. Entomol. 3: 171-175.

Overwintered boll weevils were collected from flowering yellow woolywhite, Hymenopappus flavescens Gray, during May and June in Stonewall County, Texas. Examination of the gut contents of the weevils confirmed that they were feeding on the pollen of H. flavescens. The extent to which this species is utilized for food and its importance in the spring ecology of the boll weevil is unknown. We hypothesize, however, that in the absence of fruiting cotton some overwintered boll weevils may significantly extend their life span by utilizing the pollen of yellow woolywhite as an energy source.

807. ; White, J. R.; and Wade, L. J. 1975. Late-season immigration of boll weevils into an isolated cotton plot. J. Econ. Entomol. 68: 616-618.

A small plot of cotton and pheromone traps were used to measure late season immigration of Anthonomus grandis Boheman during 1974. The test location was isolated by ca. 3 miles from commercial cotton fields. Immigratory weevil movement into the plot began Aug. 5 and continued until Nov. 11. Weevils entered the plot in numbers ranging from an estimated 500 to 10,000/acre/wk. Immigratory weevils captured on traps and those entering the plot prior to mid-October were primarily reproductive insects. Peak immigration of diapausing weevils occurred after Oct. 24. Pheromone trap and cotton plot records indicated the same pattern of weevil movement except for the 1st 3 wk of immigratory weevil activity during the 1st 3 wk of August while weevils were entering the cotton plot in numbers estimated at 1000-3000/acre/wk.

808. Russell, W. G., and Mullins, J. A. 1969. A new technique for determining direct impingement of insecticides on boll weevils. J. Econ. Entomol. 62: 1122-1123.

The direct impingement of insecticides on Anthonomus grandis Boheman was determined by affixing the weevils in toothpicks and placing them in the target area prior to insecticidal applications. While affixed to the toothpicks, the weevils lived in the field for approximately 7 days. Fluorescent particles were agitated with the insecticides and the size of spray droplets was calculated indirectly by the number of fluorescent particles that impinged on each weevil. Mortality occurred when the sum total of droplets, regardless of size, that impinged upon a weevil carried 4 more more particles.

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809. Schuster, M. F., and Boling, J. C. 1969. Insect sterilant experiments with apholate and five bifunctional aziridine chemicals in outdoor cages against the boll weevil. J. Econ. Entomol. 62: 1372-1375.

In 1964 and 1965, six bifunctional aziridine chemicals were compared as sprays on caged cotton as sterilants for control of Anthonomus grandis Boheman. Comparisons were made of the numbers of sterile eggs found, egg-punctured squares that developed to bolls, and the total bolls produced. Phytotoxicity to plants was noted. In order of decreasing effectiveness the chemicals were: OM 53264 (N,N'-(4-methyl-m-phenylene)bis-(1-aziridniecaboxamide)), OM 53061 (1-[bis(1-aziridinyl) phosphinyl] 3-(3,4-dichlorophenyl) urea), apholate, OM 53139 (N,N') hexamethylenebis (1-aziridinecarboxamide)), OM 53386 (N,N')-(4-methyl-m-phenylene)bis[2-methyl-1-aziridinecarboximide), and OM 2797 (3,9-bis(1-aziridinyl)-2,4,8,10-tetraoxa-3,9-diphosphaspiro[5,5] undecane 3,9-dioxide.

810. Scott, W. P. 1977. Suppression of boll weevils with diflubenzuron applied at different rates and spray intervals. Miss. Agric. For. Exp. Stn. Res. Rep. 3, 3 pp.

Results indicate that diflubenzuron is most effective for boll weevil control when applied two oz./acre at five- or seven-day intervals. However, tests in larger fields are needed for more precise determination of optimum application rates and intervals.

811. , and Lloyd, E. P. 1975. Suppression of the boll weevil with ULV azinphosmethyl and malathion and with LV methyl parathion. J. Econ. Entomol. 68: 827-828.

In small field plots, azinphosmethyl, malathion, and methyl parathion were equally effective in controlling populations of Anthonomus grandis Boheman. In a caged bioassay test, maximum boll weevil suppression was obtained with azinphosmethyl, and residual control was 84% after 4 days.

812. ; Lloyd, E. P.; Bryson, J. O.; and Davich, T. B. 1974. Trap plots for suppression of low density overwintered populations of boll weevils. J. Econ. Entomol. 67: 281-283.

When 4-, and 16-row trap plots were planted to cotton 2 weeks earlier than normal, both types of plots were equally effective in attracting overwintered Anthonomus grandis Boheman. When the plots were treated with aldicarb, a large proportion of the boll weevils that emerged before the squaring of the normal crop was attracted to the special plots and killed. When the plots were baited with grandlure, they attracted more of the boll weevil populations than plots that were not baited. Also, when trap plots were treated for control of Heliothis spp. 3 weeks after the sidedress application of aldicarb, the remainder of the fields did not require treatment against this pest until

after insecticide was applied to control boll weevils. Plots sprayed with methyl parathion resulted in fewer Heliothis larvae than did aldicarb treatments.

813. ; Lloyd, E. P.; and McKibben, G. H. 1975. Boll weevil control with controlled releases of methyl parathion (a preliminary report). Miss. Agric. For. Exp. Stn. Res. Rep. 1, 2 pp.

Controlled release formulations of methyl parathion prolonged the effective kill of boll weevils. The residual toxicity of the controlled release formulations did not appear to be reduced appreciably by heavy rainfall or high temperatures. Further testing is indicated by our promising preliminary results.

814. , and McKibben, G. H. 1978. Toxicity of black pepper extract to boll weevils. J. Econ. Entomol. 71: 343-344.

Extracts of ground black pepper were highly toxic to adult Anthonomus grandis Boheman when they were applied topically to the 3- to 5-day-old insects. The 24-h LD_{50} value was 9.6 μg/insect.

815. ; Smith, D. B.; and Lloyd, E. P. 1974. Direct and residual kill of the boll weevil with ULV sprays of azinphosmethyl. J. Econ. Entomol. 67: 408-410.

Tests in field plots showed that size of spray droplets, dose, and volume of ULV azinphosmethyl applied per acre were all highly significant in determining mortality of Anthonomus grandis Boheman when exposed to the residues. As volume applied per acre was increased, kill decreased. Kill by direct impingement of the droplets was less than 32%. The overall ratio between kill by residue and by direct impingement was over 4.0. With spray droplets in the size range of 100-200 μm, kill by direct impingement is less important than kill by residue.

816. Sikorowski, P. P. 1975. Microbiological monitoring in the Robert T. Gast Boll Weevil Rearing Facility. Miss. Agric. For. Exp. Stn. Tech. Bull. 71, 21 pp.

The Robert T. Gast Rearing Laboratory on the campus of Mississippi State University was designed for mass production of the boll weevil, Anthonomus grandis. During the summers of 1972 and 1973 the facility produced about one million boll weevils weekly. The chemo-sterilized male weevils were released in the pilot boll weevil eradication experiment (state-federal) in South Mississippi and adjoining parts of Alabama and Louisiana. Weevil diet is a complex medium subject to attack by many species of microorganisms. The bio-chemical changes produced by microbes alter the nutritional value of the diet. Also, some bacteria and fungi produce exotoxins which may have poisoning effects on weevils. Here we give our experience with contaminant monitoring.

817. ; Kent, A. D.; Lindig, O. H.; Wiygul, G.; and Roberson, J. 1980. Laboratory and insectary studies on the use of antibiotics and antimicrobial agents in mass rearing of boll weevils. J. Econ. Entomol. 73: 106-110.

Antibiotics were used to shield the growth medium of larvae of Anthonomus grandis grandis Boheman from microbial contamination without detectable adverse effects on boll weevil development, egg production, hatch, and male pheromone production. The standard diet overlain with medicated sand yielded 86-97% newly-emerged weevils with less than 500 bacteria/weevil as compared with 18% from diet with unmedicated sterile sand.

818. , and Thompson, A. C. 1978. Effects of bacterial load on mass reared boll weevils, Anthonomus grandis. Proceed of Int'l Colloq. on Insect Pests, Progress in Invertebrate Pathology, and 11th Meeting Soc for Invertbr. Path.: 195-196. Agric. College Campus, Prague, CSSR

Boll weevils are not mutualistically associated with bacteria and under natural conditions normally bacteria are not present in the gut. Solitary, wild weevils feed on noncontaminated cotton buds containing compounds that have anti-bacterial properties. Data accumulated during the past 5 years of operation of the Gast Laboratory show that the boll weevil gut could support a highly varied bacterial population, and relative composition of the flora may change from day to day. The data from this study showed that bacterially contaminated weevils produced less pheromone, and had lower lipid and amino acid levels than noncontaminated insects. With implementation of improved sanitary measures the problem of bacteria contamination has been essentially eliminated.

819. , and Thompson, A. C. 1980. Effects of internal bacterial contaminants on mass reared boll weevils (Anthonomus grandis Boheman). Miss. Agric. For. Exp. Stn. Tech. Bull. 103, 6 pp.

Field collected weevils normally have a small number of bacteria in the gut. Data accumulated over the past five years of operation of the Gast Laboratory show that the boll weevil gut can support a highly varied bacterial population and that the relative composition of the flora may change from day to day. Our data show that contaminated weevils produced less pheromone and have lower lipid and amino acid levels than noncontaminated insects. This adverse effect on quality of performance of mass reared adults makes them of little value in an eradication program. Sanitation practices put into effect at the Gast Laboratory as a result of these studies have essentially eliminated bacterial contamination, This, to our knowledge, is the first attempt to evaluate the effects of bacterial contamination on the quality of artifically reared weevils or any other insectary reared insect.

820. ; Wyatt, J. M.; and Lindig, O. H. 1977. Method for surface-sterilization of boll weevil eggs and the determination of microbial contamination of adults. Southwest. Entomol. 2: 32-36.

Surface-sterilization studies of Anthonomus grandis Boheman eggs showed that sodium hypochlorite (0.1 and 0.2%) and formaldehyde (10%) produced eggs free of contamination. Treatments had an insignificant effect on egg hatch. However, eggs treated with sodium hypochlorite were buoyant due to the small gas bubbles that adhered to the egg surface. This characteristic made sodium hypochlorite more difficult to use than formaldehyde. The bacterial content of adult weevils hatched from eggs surface-sterilized with 0.8% formaldehyde (control) averaged 1.2×10^5 for aerobic and 4.6×10^4 for anaerobic species; 0.2% sodium hypochlorite and 10% formaldehyde averaged 2 each and 1 each, respecitvely, for aerobic and anaerobic bacteria per insect. It is concluded from this study that 10% formaldehyde is the more effective and practical method for surface-sterilization of large volumes of weevil eggs.

821. Simmons, C. L., and Wilson, C. A. 1975. Studies to determine the effects of the boll weevil eradication experiment on the honey bee, Apis mellifera L. Am. Bee J. 115: 356, 358, 360, 372.

Insecticides used in both areas were toxic to worker bees. Colonies could withstand severe mortalities, however, and survive. Unhatched sealed brood was probably responsible for survival as the entire field force and many of the hive bees were killed. Dead bees often completely covered the bottom board. A thorough weekly cleaning of the hives also helped to save many colonies. These observations agree with those of Sanders (1975). Only four hives, all adjacent to fields in the normal area, were completely killed by insecticides during the spray season. Overwintering losses, however, were much greater in the eradication area. Honey stores in the normal area were sufficient for the colonies to recover from the heavy bee kills and still survive the winter. In the eradication area, continuous applications of insecticides starting in early July, resulted in a continuous light worker bee mortality. This, along with a dry fall,

resulted in very light honey stores. Consequently, there was a 35 percent overwintering loss of hives in the eradication area. Exposure to pesticides caused a loss in worker bees, especially the field force. This caused an immediate reduction in honey production which led to overwintering losses. Heavy bee kills also made the colony more susceptible to natural enemies of the honey bee, especially to the wax moth, Galleria mellonella (L.).

822. Singh, I. D., and Weaver, J. B., Jr. 1972. Growth and infestation of boll weevils on normal-glanded, glandless, and high-gossypol strains of cotton. J. Econ. Entomol. 65: 821-824.

Field, cage, and laboratory tests with normal-glanded, glandless, and high-gossypol strains of cotton, Gossypium hirsutum L., showed that Anthonomus grandis Boheman preferred glandless or normal-glanded cotton to high-gossypol cotton for feeding and oviposition. Boll weevils that emerged from punctured squares of high-gossypol strains were smaller than those emerging from squares of normal-glanded and glandless cotton. Results of this study suggest that boll weevils show nonpreference for strains of cotton containing a high level of gossypol in squares.

823. Slatten, B. H., and Larson, A. D. 1967. Mechanism of pathogenicity of Serratia marcescens. 1. Virulence for the adult boll weevil. J. Invertebr. Pathol. 9: 78-81.

The LD_{50} of the bacterium, Serratia marcescens, for the adult boll weevil, Anthonomus grandis, was 5.1 ± 1 organisms per weevil by intrahemocoelic inoculation. Ingestion of grossly contaminated food also infected the weevils.

824. Slosser, J. E. 1978. The influence of planting date on boll weevil management. Southwest. Entomol. 3: 241-246.

Boll weevil, Anthonomus grandis Boheman, population development and cotton squaring trends are compared between an early planted cotton field and several fields with later planting dates. In the early planted field, peak weevil populations were 4.6 times greater than in the late planted fields, and high weevil populations delayed plant maturation in the early planted field. As many weevil punctured squares were produced in the 1 early planted field as in 4 of the late planted fields. The early field produced 0.6 bales/ha as compared to an average of 1.3 bales/ha in the later planted fields.

825. , and Boring, E. P., III. 1980. Shelterbelts and boll weevils: a control strategy based on management of overwintering habitat. Environ. Entomol. 9: 1-6.

Present-day boll weevil, Anthonomus grandis Boheman, problems in the northern Rolling Plains of Texas are linked to shelterbelt plantings made during the late 1930's. Available evidence suggests that boll weevil populations surviving the winter in 0.6 ha of shelterbelt litter may infest and reach damanging levels in 13.2 ha of cotton by mid-Aug. Where heavy sustained boll weevil infestations are not controlled, an estimated $1786 is lost due to yield reduction in the 13.2 ha. Several potential solutions to the boll weevil problem are presented. These solutions include habitat destruction or management, and the use of insecticides, biotic agents, and fire. The use of these techniques is extended to the management of other habitat types such as rangeland shinnery oak, Quercus havardii Rybd. An impending move to renew shelterbelt plantings, particularly in the High Plains where boll weevils do not overwinter, is discussed. The lessons learned in the Rolling Plains regarding the interaction between boll weevils, shelterbelts, and cotton should be taken as a serious guideline to the management of new shelterbelt plantings.

826. , and Oakes, S. N. 1977. A comparison of fruiting characteristics and insect damage amont the cotton varieties Tamcot SP-37, Lockett 4789A, Lockett 77-4 and Lankart Sel. 611. Tex. Agric. Exp. Stn. Prog. Rep. PR-3433, 3 pp.

Growth characteristics, production potential, and response to insect pressure were compared in cotton varieties Tamcot SP-37, Lockett 77-4, Lockett 4789A, and Lankart Sel. 611. Yields were significantly different, but varietal resistance to the bollworm, Heliothis zea (Boddie), boll weevil, Anthonomus grandis Boheman, or cotton fleahopper, Pseudatomoscelis seriatus (Reuter), was not detected. The two new varieties, Tamcot SP-37 and Lockett 77-4, performed best because they produced the most squares and bolls and had a faster rate of square production in early season.

827. Smalley, D. L., and Ourth, D. D. 1979. Bacterial genera isolated from field-collected (diapausing) and laboratory-reared cotton boll weevils, Anthonomus grandis (Coleoptera: Curculionidae). J. Invertebr. Pathol. 34: 158-63.

Little data exist on the bacterial flora of the cotton boll weevil, Anthonomus grandis, which is a common insect pest to cotton farmers in the United States. This investigation determined the total numbers of aerobic and anaerobic bacteria in diapausing field-collected boll weevils and active adult laboratory-reared boll weevils. Identifications were made of aerobic genera isolated from field-collected and laboratory-reared boll weevils that had previously been surface sterilized. The genera found, in order of decreasing frequency, in the field-collected boll weevils were Lactobacillus, Erwinia, Flavobacterium, Enterobacter, and Pseudomonas. The genera found, in order of decreasing frequency, in the laboratory-reared boll weevils were Lactobacillus, Pseudomonas, Streptococcus, Erwinia, Enterobacter, and Flavobacterium, Lactobacillus was the most frequently found genus in both groups.

828. , and Ourth, D. D. 1979. Phagocytic and humoral immunity to Serratia marcescens of the adult cotton boll weevil, Anthonomus grandis. Fed. Proc. Fed. Am. Soc. Exp. Biol. 38: 1002.

This investigation determined phagocytic, lysozymal and bactericidal defensive responses of adult laboratory-reared cotton boll weevils. Phagocytosis was first demonstrated in boll weevils at 3 hours following injection of live Serratia marcescens. Maximum phagocytosis of 16% of plasmatocytes examined was found at 16 hours post-injection. Lysozyme activity was demonstrated in both inoculated and uninoculated boll weevils. A mean lysozyme activity peak of 7 μg/ml was found at 48 hours following inoculation of heat-killed Serratia marcescens. Bactericidal activity was demonstrated in inoculated boll weevils but not in uninoculated boll weevils. A mean bactericidal activity peak occurred at 24 hours following inoculation of heat-killed Serratia marcescens. Lysozymal and bactericidal activities were shown to be separate functions.

829. Smith, D. B. 1977. Equipment for capturing fallen cotton squares. U.S. Dep. Agric. Tech. Bull. 1561, 16 pp.

Equipment to relocate and remove fallen boll weevil infested cotton squares was designed, constructed, and evaluated. Circular brushes mounted in tandem moved more squares away from the row area than a similar single brush. Neither brush system moved adequate numbers of squares beyond 30.5 cm. The addition of an air nozzle to the tandem brush system increased square movement, at 8.1 km/hr ground speed, from 53.4 to 62 percent beyond 25.4 cm. A variable profile nozzle was more effective and versatile than a constant area nozzle for removing fallen squares. Square removal and capture tests were run with a two-row, high-clearance machine equipped with 33-cm length nozzles. This equipment removed about 80 percent of the squares and retained over 60 percent of the total fallen squares. Separation and deflection plates in the plenum chamber increased the square retention efficiency at the expense

of removal efficiency.

830. , and Burt, E. C. 1970. Effects of the size of ULV droplets within cotton foliage both inside and immediately downwind from a treated swath. J. Econ. Entomol. 63: 1400-1405.

Results of field tests using controlled sizes of droplets showed that uniformity of deposit in the treated area increased by both controlling sizes and by increasing the size of droplets. Drops per square inch deposited within cotton foliage were sampled on 1-ft intervals. The deposit at a particular level was found to be 50% of the deposit taken 1-ft above the given sample. A droplet of approximately 140 μ appears to be the minimum size that can be released, without other controlling factors, and be deposited dependably in or near the treated area.

831. ; Burt, E. C.; and Lloyd, E. P. 1975. Selection of optimum spray-droplet sizes for boll weevil and drift control. J. Econ. Entomol. 68: 415-417.

Within the limits of the droplet sizes tested, smaller droplets provided better plant coverage and, thus, insect control, but also increased drift. Therefore, a compromise was necessary in determining an acceptable droplet size that would provide good coverage without increasing drift. For ULV applications of azinphosmethyl with ground equipment, a droplet size between 140 and 200 μ provided an adequate solution for control of Anthonomus grandis Boheman and drift problems.

832. ; Threadgill, E. D.; and Burt, E. C. 1973. Aerodynamic testing of cotton squares. Trans. ASAE 16: 222-226.

Design data for the development of improved equipment to capture fallen boll weevil infested cotton squares have not been available. Due to the lack of

sufficient information, improvements in such equipment have been based largely on an intuitive feeling rather than sound knowledge. This work has shown the effects of square area, dynamic pressure, and square orientation angle on both the net lift and resultant forces. The results indicate that the zero square orientation angle (bracts upwind) created the largest resultant forces and the 180 degree orientation angle (bracts downwind) the largest net lift forces. For the latter position, the larger squares produced fewer positive net lift forces than the smaller squares. For design purposes, the horizontal air velocity should be 58 fps or greater. A resultant forces coefficient-Reynolds number relationship was not established due to considerable scatter in the data and the narrow range of Reynolds numbers encountered.

833. Smith, J. W.; Scott, W. P.; and Parencia, C. R. 1978. Predator-prey ratios for control of Heliothis species on cotton. Proc. 1978 Beltwide Cotton Prod. Res. Conf., pp. 111-113.

For many reasons including resistance problems, residues, and the increasing cost of insecticides, cotton insect control is in a period of transition from almost total reliance on chemicals to pest population management. But for pest management, knowledge of the crop ecosystem is essential. Within field, this means information about the cotton plants, weeds, soil and its biota, pest species with their associated natural diseases and mortality due to beneficial insects, and the influence of man. Moreover, a multitude of other interacting factors must be understood such as the effect of other nearby agricultural crops, woods, streams, and weedy uncultivated areas. The use of beneficial arthropods as a part of cotton pest management has engendered considerable discussion, but practical information is lacking. In view of the lack of necessary information, researchers in USDA are particularly interested in determining the role of entomophagous arthropods in controlling Heliothis spp. in cotton pest

management systems. An "Optimum Pest Management" trial will therefore be conducted in Panola County, Mississippi concurrently with the "Boll Weevil Eradication" trial scheduled for North Carolina in 1978. The economic, biological, social and environmental impacts of the two methods of controlling the boll weevil, Anthonomus grandis Boheman, can then be compared by environmental, economic, and biological evaluation teams. Finally the data thus developed will be made available to the overall evaluation team that will make the final judgment of the best approach to boll weevil control. USDA has the lead responsibility for developing data for the biological evaluation team and for conducting supporting research for both trials. In anticipation of this responsibility, a prototype program was conducted in 1977 in Panola and Pontotoc Counties, Mississippi to develop baseline data and to evaluate and refine techniques that would be used in the two trials.

834. Smith, R. F. 1978. History and complexity of integrated pest management. In Edward H. Smith and David Pimentel (eds.), Pest Control Strategies, pp. 41-43. Academic Press, New York.

The concept of integrated pest management is not a distinct development in crop protection, but is an evolutionary stage in the history of pest control. It is significantly different from earlier strategies in that it represents a new conceptual approach that sets crop protection in a new context within a crop production system. Many components of the integrated pest management concept were developed in the late nineteenth and early twentieth centuries, but integrated pest management as it is now conceived is unique because it is based on ecological principles and integrates multidisciplinary methodologies in developing agroecosystem management strategies that are practical, effective, economical, and protective of both public health and the environment. The efforts of early crop protection specialists to control pests with ecologically

based cultural methods were not satisfactory; consequently, entomologists, plant pathologists, and later, weed scientists, became preoccupied with the discovery and development of pesticides that were economical and effective. Unfortunately, chemical methods were often not used to supplement cultural and biological methods of control but to supplant them. Our state of technology and understanding of host-pest interactions has now evolved to the point that an integration of pest control tactics for the control of a given class of pest (e.g., insects, plant pathogens, etc.) and for multiple classes of pests is not only feasible but necessary, given the inadequacies of single-methods, single-discipline approaches and their potential for undesirable effects on nontarget beneficial and pest species.

835. ; Huffaker, C. B.; Adkisson, P. L.; and Newsom, L. D. 1974. Progress achieved in the implementation of integrated control projects in the USA and tropical countries. EPPO Bull. 4: 221-229.

General accomplishments of a large co-operative research program in the United States is reviewed. Examples of the developments of integrated pest control for the cotton and soybean agro-ecosystems are given. The uses of simulation models are emphasized. Progress of integrated control in tropical counties is discussed.

836. Snodgrass, G. L.; Johnson, W. L.; and Cross, W. H. 1979. Efficiency of the Leggett trap in capturing responding boll weevils. J. Econ. Entomol. 72: 378-379.

Leggett traps watched continuously during daylight hours were observed in 2 tests involving different techniques to capture 51 and 59% of responding Anthonomus grandis grandis Boheman. Capture efficiency was greatly affected by the trap part on which boll weevils landed; 53.4% of those landing on the trap liners were captured compared with only 28.6% of those landing

on other trap parts. Boll weevils remained on the traps an avg of 18.47 min before they were captures; those not captured remained on traps an avg of 14.58 min before leaving.

837. Souza, J. P. de, and Goncalves, A. M. R. 1978. Alternative route to three of the four terpenoid components of the boll weevil sex pheromone. J. Org. Chem. 43: 2068-2069.

The ecological imbalance and environmental pollution due to insecticide residues has stimulated a great interest in the synthesis of pheromones, since they may provide a generally nontoxic method of biological control of insect populations. A pheromone complex emitted by live male boll weevils (Anthonomus grandis Boheman) comprising the four terpemoid compounds (+)-cis-2-isopropenyl-1-methylcyclobutaneethanol (1), (Z)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol (2), (Z)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (3), and (E)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (4) were identified and first synthesized by Tumlinson et al. We report a simple sequence of reactions which afford the synthesis of alcohol 2 and aldehydes 3 and 4 in high yield from readily available starting materials.

838. Sprague, G. F., and Dahms, R. G. 1972. Development of crop resistance to insects. J. Environ. Qual. 1: 28-34.

The development of host resistance to insect pests offers promise of reducing yield losses as well as a material reduction in the use of insecticides. A review of progress and the current situation is presented for selected insect pests, Hessian fly (Mayetiola destructor), European corn borer (Ostrinia nubilalis), boll weevil (Anthonomus grandis), corn earworm and cotton bollworm (Heliothis zea), pea aphid (Acyrthosiphon pisum), spotted alfalfa aphid (Therioaphis maculata), potato leaf hopper (Empoasea fabae), and the alfalfa weevil (Hypera postica). With the exception of the Hessian fly the only feasible

control for this group of insects, prior to the development of resistant types, has been through use of chemicals. Marked progress has been achieved in developing commerically useful host-resistance to this group of insects with the exception of the cotton bollworm and boll weevil. Even here types differing in various components of resistance have been identified but the combination of these characteristics into an acceptable commercial variety remains to be accomplished. Increased emphasis is being placed on host-plant resistance. Success in such efforts requires the close cooperation of entomologists, geneticists, and breeders.

839. Sprott, J. M.; Lacewell, R. D.; Niles, G. A.; Walker, J. K.; and Gannaway, J. R. 1976. Agronomic, economic, energy and environment implications of short-season, narrow-row cotton production. Tex. Agric. Exp. Stn. Misc. Publ. MP-1250C, 23 pp.

The agronomic, environmental, energy use and economic implications of narrow-row, short-season cotton production were evaluated, based on data from a study conducted in Frio County, Texas in 1974. Short-season, narrow-row cotton production reduced the energy use per acre from 3,624,453 kcal to 2,445,378 kcal, or a savings of 33 percent. More dramatically, the kcal required per pound of lint declined from 7,249 kcal to 3, 197 kcal, or a savings of 56 percent. This production technique also required 26 percent fewer pounds of active ingredients in insecticides and herbicides per acre. Economic evaluations indicated a potential savings in cost per pound of lint of 43 percent, from 47.6¢/lb. under "typical" Frio County production techniques to 26.9¢/lb. using the narrow-row, short-season technique. Overall, a short-season system is in harmony with environmental and energy use goals, in addition to being attractive to the producer. Consumers ultimately should benefit through reduced retail price of cotton fibers, in addition to the environmental protection afforded by the narrow-row, short-season cotton production technique.

840. Sterling, W. L. 1971. A complete cotton pest protection system. Prog. Farmer (Spring Bonus Issue): 24.

Down the road, cotton growers can look to other highly promising tools in their cotton protection systems: release of sterilized insects into native populations to disrupt reproduction is being tested with pink bollworms and boll weevils. Another approach is to place a chemical sterilizing material in the field and lure native insects to it. Juvenile hormones may be introduced into native populations of boll weevils, pink bollworms, and bollworms to prevent them from reaching adulthood and reproducing. Fields may be "seeded" with insects with genetic deficiencies, such as the inability to diapause, to break the insect life cycle. Artificial lighting of cottonfields has been demonstrated by one Texas A&M University researcher to prevent or reduce egg-laying by bollworm and budworm moths. Biological controls - rearing and releasing overwhelming numbers of beneficial insects in cottonfields or spraying the crop with a virus or bacteria - may provide control of the bollworm and budworm complex without harmful effects on beneficial insects or the environment. Cotton varieties resistant to insects, such as fleahoppers, lygus, bollworms, budworms, and weevils, are being developed. As these dramatic new weapons become available, it will become increasingly important that cotton producers become "systems oriented." That way, they will be able to put together a complete crop protection program that will be effective and economical.

841. . 1971. Winter survival of the boll weevil in the High and Rolling Plains of Texas. J. Econ. Entomol. 64: 39-41.

Cage studies of the overwintering ability of Anthonomus grandis Boheman showed that higher percentages of individuals reared on cotton bolls survived the winter than did individuals reared on squares or a cottonseed meal diet, or adults collected from the field. The time during the fall that boll weevils were placed into overwintering cages did not affect the time of emergence in

the spring. However, boll weevils installed in cages between Oct. 15 and Nov. 3 had higher survival rates than weevils installed earlier or later. Peak boll weevil emergence occurred in mid-May.

842. . 1972. Photoperiodic sensitivity in the ontogeny of the boll weevil. Environ. Entomol. 1: 568-571.

Exposure of parent boll weevils to several photoperiods had no measurable influence on the incidence of diapause in the offspring. Photoperiod was largely unable to override dietary influences on the regulation of boll weevil diapause.

843. . 1974. Sampling problems with cotton insects. IPM, The Principles, Strategies, and Tactics of Pest Population Regulation and Control in Crop Ecosystems. Proceed. Workshop on Evaluation of role of Predators in Crop Ecosystems, pp 22-23. Intl. Cts. for Bio. Con., U. of California, Berkeley and Riverside.

In our research sampling we think taking many single plant samples in a stratified random technique has definite advantages. The greater the number of samples we take the lower the standard error becomes. Also, by stratifying samples across a field minor changes in plant growth patterns and arthropod dispersion patterns can frequently be detected. Advantages of sequential sampling are its time-saving features and predetermined probabilities of correctly assessing the population. These probabilities are usually set at 80 to 90%. The stratified-random research sampling technique using both whole-plant and D-Vac sampling is very time-consuming and expensive. Since there are many small samples the problem of data management becomes very difficult. We have largely solved this problem by adopting IBM Port-A-Punch cards for recording raw data in the field or laboratory. Using this technique we can often have data analyzed 15 minutes after it comes in from the field. The primary limitation with sequential sampling is that each sample must be recorded as it is taken. Thus,

the sequential sampling plan must be taken into the field on a clip board or in the pocket for recording purposes. Also, most of the plans are still experimental, since they have not been demonstrated conclusively.

844. . 1975. Sequential sampling of cotton insect populations. Proc. 1975 Beltwide Cotton Prod. Res. Conf., pp. 133-135.

The sequential sampling package is designed primarily for use in making decisions for cotton insect pest management but it can also be used in research. For example, when any type of action is to be taken such as releasing predators at various prey densities on any prey insect population at an established population number, sequential sampling plans can be developed and used very easily for each prey density. There is also excellent potential for using sequential sampling for making weed and disease management decisions.

845. . 1978. Fortuitous biological suppression of the boll weevil by the red imported fire ant. Environ. Entomol. 7: 564-568.

The efficacy of the red imported fire ant (Solenopsis invicta Buren) as a predator of larval stages of the boll weevil (Anthonomus grandis Boheman) was evaluated in 2 areas of Texas. In the Trinity River area the ants consumed up to 85% of the weevils with a weekly avg of 66%. Ants never consumed more than 37% of the weevils in the Brazos-Navasota River area and averaged 22% in Aug. The fire ant exhibits characteristics that may make it a valuable predator of cotton insect pests. It tends to disperse fairly uniformly across cotton fields at high densities and tends to increase in abundance as the growing season progresses.

846. . 1978. Imported fire ant . . . may wear a gray hat. Tex. Agric. Prog. 867, 24(fall): 19-20.

Red imported fire ants are generally regarded as very serious insect pests in the southeastern United States. Implements striking the ant mounds may be damaged, and the insect can be a nuisance in yards, playgrounds, and other areas where

people congregate. But, evidence is accumulating which indicates that the ant is not all bad. Recent research suggests that we should take a new look at the red imported fire ant (Solenopsis invicta Burne) and evaluate its possible benefits. For example, fire ants were observed to kill 66 percent of the young boll weevils in an East Texas cotton field during 1977. As a result, no yield losses due to weevil damage were observed in this dryland field, and yield was slightly more than 1 bale per acre with no insecticides used for boll weevil control.

847. , and Adkisson, P. L. 1966. An artificial diet for laboratory cultures of boll weevil larvae and adults. J. Econ. Entomol. 59: 1074-1077.

Six generations of boll weevils, Anthonomus grandis Boheman, were reared in the laboratory on cottonseed meal diet in the complete absence of cotton squares, flowers, or bolls formerly used for adult food and oviposition. These weevils maintained an average weight of 18 mg and within 4 generations fecundity increased from an average of 196 to 751 eggs per female. This diet eliminates the necessity of preparing separate diets for adult and larval rearing, as well as the need for maintaining greenhouse cotton during the winter.

848. , and Adkisson, P. L. 1966. Differences in the diapause response of boll weevils from the High Plains and central Texas and the significance of this phenomenon in revising present fall insecticidal control programs. Tex. Agric. Exp. Stn. Bull. B-1047, 7 pp.

Boll weevils on the High Plains of Texas enter diapause considerably earlier in the fall and in greater percentages than do those in Central Texas. This difference in response is due not only to differences in environment between the two areas, namely, earlier occurring more severe winters in the High Plains than in Central Texas, but also to a difference in the genetic makeup of the two weevil photoperiods. Short days induce diapause in both populations; however, significantly greater percentages of the High Plains weevils entered diapause

under inductive photoperiods than did those from College Station or Presidio. It was concluded that the boll weevil is becoming adapted to the environment of the High Plains and a distinctive photoperiodic race of the species may have already evolved in this area. It is suggested that a new type of approach for reducing diapausing boll weevils might be particularly effective in the High and Rolling Plains. This approach would have two phases. Phase I would be directed towards killing the last reproductive generation of adult females before they lay the eggs that give rise to the potentially overwintering adults. This would be accomplished with insecticidal applications made at 5-day intervals during September. Phase 2 would have as its objective the killing of any diapausing adults in October that may have survived earlier insecticidal treatments or that may have developed from eggs laid between applications in September.

849. , and Adkisson, P. L. 1970. Seasonal rates of increase for a population of the boll weevil, Anthonomus grandis, in the High and Rolling Plains of Texas. Ann. Entomol. Soc. Am. 63: 1696-1700.

Life, fertility, and life-expectancy tables, were computed for 13 boll weevil cohorts reared in the field cages and in an insectary. The increase in female offspring per female per week ranged from 1.56 for adults produced from eggs deposited Aug. 16, 1966, to 0.63 for eggs deposited Sept. 26, 1966. However, the number of female offspring produced per female per generation ranged from 20.6 for adults emerging from eggs deposited Aug. 30, 1966, to 0.02 for eggs deposited Oct. 3, 1966. Seasonal life expectancy for eggs during 1966 ranged from about 1 to 7 weeks for eggs deposited Aug. 2 and Sept. 29, respectively. However, the life expectancy of teneral adults ranged from almost 3 to 10 weeks during this same period. This, adults had a greater life expectancy than eggs. Adults emerging from cohorts started after mid-August had lower mortality rates

than cohorts started during July to mid-August. This fact indicates that adult numbers should tend to accumulate in cotton fields after mid-August.

850. , and Adkisson, P. L. 1971. Seasonal biology of the boll weevil in the High and Rolling Plains of Texas as compared with previous biological studies of this insect. Tex. Agric. Exp. Stn. Misc. Publ. MP-993, 12 pp.

Field-cage and insectary studies provided data on developmental periods of boll weevils reared on squares, bolls and a cottonseed meal diet. Egg to adult developmental periods for square-reared boll weevils ranged from 13.6 to 52.5 days for adults developing from eggs deposited July 18 and August 10, respectively. Boll-reared weevils required from 11 to 31 days longer than square-reared weevils to develop to the adult stage with the developmental period increasing as the season progressed. No adults developed from eggs implanted after October 15 during both 1965 and 1966. Diet-reared boll weevils required an egg to adult developmental period that ranged from 63 to 17 days for adults developing from eggs deposited on March 17 and July 20, respectively. Average ambient temperatures ranging from 54 to 87° F. apparently caused the egg to adult developmental period to increase from 12.5 to 55 days for the two temperatures, respectively. Pre-oviposition periods ranged from 4 to 11 days for adults developing from eggs deposited on July 3 and September 26, respectively. Also, the egg to egg developmental periods ranged from 16 days to 52 days for adults developing from eggs deposited on July 3 and September 26, respectively. Variation in emergence periods increased as the season progressed.

851. , and Adkisson, P. L. 1978. Population dynamics of the boll weevil inhabiting the High and Rolling Plains of Texas. Environ. Entomol. 7: 439-444.

Seasonal field increases in the number of boll weevils in Dickens and Kent

Counties of Texas were found to fit logistic growth curves. Boll weevil numbers increased exponentially through July, Aug., and Sept. at rates up to ca. 2.70-fold/wk in an untreated field compared to 1.74-fold avg in insecticide treated fields. During Oct. the population growth rate slowed and finally reached zero. The relation between the mean number of squares available to each weevil and percentage of weevil damaged squares fit a curvilinear model. This model can be used to provide an estimate of the number of adult weevils per ha based on % damaged squares and an estimate of the number of squares per ha. Conversely, numbers of damaged squares can be estimated based on numbers of adult weevils.

852. ; Adkisson, P. L.; and Rummel, D. R. 1967. Effects of the diapause boll weevil control program on the size and rate of increase of boll weevil populations in the High Plains of Texas. Tex. Agric. Exp. Stn., Dep. Entomol. Rep. 7, 11 pp.

Effects of the current diapause boll weevil control program on the size and rate of increase of boll weevil populations in the High and Rolling Plains during 1966 were studied in fields which had been treated with ultra-low-volume applications of malathion during the fall months of 1964, 1965 and 1966. The size of the population in these fields were compared to that of one in a field which was never treated with insecticides. Results showed that the populations were extemely small in both treated and untreated fields until early September. During September and October, the estimated number of weevils in the untreated field increased almost 90-fold, increasing from 399 to more than 35,000 adults per acre. In contrast, the populations in the treated fields were held stable during the fall months at relatively small numbers per acre. The difference in the size of the two populations show the effectiveness of the present diapause boll weevil control program in reducing populations. However, the rate of increase of the population in the untreated field indicate that if the present control efforts were discontinued that the boll weevil has the reproductive

capacity to increase its numbers within one year to the levels that existed in 1964. For this reason, present control efforts should be continued in order to prevent the boll weevil from becoming reestablished on the High Plains.

853. , and Haney, R. L. 1973. Cotton yields climb, costs drop through pest management systems. Tex. Agric. Prog. 662, 19(Summer): 4-7.

The Texas Department of Corrections Pest Management Systems consisted of the following: 1. Boll weevil. (a) Early stalk destruction, (b) Insecticide treatments in the fall for diapause control; 2. Fleahoppers. (a) Careful sampling to make control decisions, (b) Low dosages of insecticides used if needed, and (c) If insecticide used, make applications no later than first 3 weeks of fruiting; 3. Budworms-bollworms. (a) Careful sampling to make control decisions, and (b) Tolerate high damage level before initiating chemical control (15% damaged squares). Hopefully, use of insecticide is avoided; and 4. Advantage. (a) Increase earliness of crop, (b) Increase yields (c) Lower insecticide cost, (d) Decrease pollution, and (e) Increase producer profits.

854. ; Jones, D.; and Dean, D. A. 1979. Failure of the red imported fire ant to reduce entomophagous insect and spider abundance in a cotton agroecosystem. Environ. Entomol. 8: 976-981.

Large numbers of the red imported fire ant, Solenopsis invicta Buren, were unable to pauperize the predator arthropod fauna of a cotton field in east Texas. None of the 47 taxa sampled was significantly reduced as a result of S. invicta predation. Because of its predatory habits on boll weevils, Anthonomus grandis grandis Boheman and Heliothis spp., and its failure to simplify the predator fauna, S. invicta must be considered an important predator in cotton agroecosystems where it is abundant. The evidence suggests that S. invicta is a fairly specialized predator though probably a polyphagous scavenger.

855. , and Lincoln, C. 1978. Survey, detection, and economic thresholds. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, pp. 4-14.

The two basic prerequisites in developing effective pest management systems are 1) fairly good sampling and 2) confidence in the use of sound economic levels of pest populations or damage. Thus, economic thresholds are considered in this paper along with survey and detection, since these subjects are essentially interdependent in pest management programs. Sampling populations in management programs would be unnecessary unless there were some level at which management decisions could be made. Other objectives of sampling for boll weevil are for eradication programs or for research purposes. Sampling in eradication programs is designed to detect low density populations and survey the geographical area inhabited by live individuals. Sampling for research purposes poses another series of constraints on the technique used. In field research the main objective is to determine the effects of various environmental factors on boll weevil abundance and dynamics.

856. , and McDaniel, S. 1978. Is the fire ant a friend or a foe? Farmer Stockman 91(Nov.): 6-7.

The red imported fire ant is generally regarded to be a very serious insect pest in the southeastern United States. Hay mowers striking the ant mounds may be damaged and the insect can be a nuisance in yards, playgrounds and other areas where poeple congregate. However, evidence is accumulating that indicates the ant is not all bad. Recent research suggests that we should take a new look at the red imported fire ant (Solenopsis invicta Burne) and evaluate possible benefits of this insect. For example, fire ants were observed to kill 66 percent of the young boll weevils in an east Texas cotton field during 1977. As a result, no yield losses due to weevil damage were observed in this dryland field. The field yielded slightly over one bale per acre with no insecticides used for boll weevil control.

857. Stewart, J. R.; Glover, D., Jr.; and Torries, W. J. 1972. Automated system for mass producing diet for boll weevil adults. J. Econ. Entomol. 65: 861-862.

Increased production demands on laboratories mass rearing the boll weevil prompted development of additional improvements in the mechanization of rearing techniques. An automated system for producing adult diet was devised which reduced labor requirements $350/million weevils.

858. Still, G. G., and Leopold, R. A. 1979. The elimination of (N-[[(4-chlorophenyl)amino]carbonyl]-2,6-difluorobenzamide) by the boll weevil. Pestic. Biochem. Physiol. 9: 304-312.

Boll weevils, Anthonomus grandis Boheman, were either dipped in or injected with a solution of [^{14}C]diflubenzuron (N-[[(4-chlorophenyl)amino]carbonyl]-2, 6-difluorobenzamide) or fed on cotton squares that had been treated with the chemical to determine its turnover time and metabolic fate. No significant differences were observed between male and female weevils in their ability to eliminate [^{14}C]diflubenzuron. Only minor differences were observed when immersion and injection treatments were compared. When weevils were treated with 66.3 ng of [^{14}C]deflubenzuron per weevil by injection, the insects contained 13 to 15% of the radiolabel after 6 days and 4 to 6% after 13 days. The remainder of the radiolabel was in the frass. When weevils fed for 66 hr on cotton squares that has been treated with a wettable [^{14}C]diflubenzuron preparation (Dimilin W-25), the insects averaged 120 ng of diflubenzuron per weevils. Forty-four hours after removing insects from the treated squares, 50% of the radiolabel had been excreted. In all cases, the radiolabel found in the frass or in the weevil was unchanged diflubenzuron. There were no data to indicate that the boll weevil could metabolize appreciable amounts of diflubenzuron.

859. Stokes, R. A.; Coppedge, J. R.; Bull, D. L.; and Ridgway, R. L. 1973. Use of selected plastics in controlled release granular formulations of aldicarb and dimethoate. J. Agric. Food Chem. 21: 103-108.

Granular formulations of aldicarb prepared with cellulose acetate, polyamide, polyster, polyvinyl chloride, polyurethane, and urea-formaldehyde and granular formulations of dimethoate prepared with cellulose acetate, polyvinyl chloride, and petroleum charcoal released the insecticides more slowly into soil and water than did the standard corn cob formulations of the two insecticides. Greenhouse bioassays indicated that most plastic formulations of aldicarb were more effective than the standard corn cob formulation in extending the period of systemic insecticidal activity of aldicarb against adult boll weevils, Anthonomus grandis Boheman. Greenhouse bioassays with cotton aphids, Aphis gossypii Glover, and radioassays of plants grown in soil treated with selected granular formulations indicated that certain plastic and charcoal formulations of dimethoate extended the uptake from soil and the biological activity.

860. ; Coppedge, J. R.; and Ridgway, R. L. 1970. Chemical and biological evaluation of the release of aldicarb from granular formulations. J. Agric. Food Chem. 18: 195-198.

The relative rates of release of aldicarb (newly accepted common name for 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime; Temik, UC-21149) from granular formulations into water and soil were affected by the type base material, the type and percentage of binder used, and the mesh size. Useful correlations between release rates in a laboratory water immersion test and extended biological activity were obtained. Bioassay of the new growth of treated cotton plants with boll weevil, Anthonomus grandis Boheman, showed that prolonged uptake of the toxicant in the plant occurred with formulations which had slow rates of release in a laboratory water immersion test. Also, mixtures of granular formulations with fast and slow

rates of release gave a greater initial uptake than occurred with a formulation with a slow rate of release and a more prolonged uptake than occurred with a formulation with a fast rate of release.

861. Stoner, A. 1968. Sphaeralcea spp. as host of the boll weevil in Arizona. J. Econ. Entomol. 61: 1100-1102.

All boll weevils that crawled from the tip collections and those removed from cotton bolls fed readily on fruits buds and flowers of S. emoryi but failed to reproduce. The weevils appeared normal, large and robust. Those found on the tip collections had probably emerged from diapause in ground trash or other sites and then moved into Sphaeralcea, but probably none were produced on it. Sphaeralcea spp., although not true hosts, are available as food plants and boll weevils will feed on them. Thus, in Arizona the plants can at least provide food in the interval between boll weevil emergence from hibernation and the availability of cotton.

862. Struck, R. F.; Frye, J.; Shealy, Y. F.; Hedin, P. A.; Thompson, A. C.; and Minyard, J. P. 1968. Constituents of the cotton bud. IX. Further studies on a polar boll weevil feeding stimulant complex. J. Econ. Entomol. 61: 270-274.

Techniques were used to concentrate and fractionate the polar feeding stimulant for the boll weevil, Anthonomus grandis Boheman, that is found in the buds of cotton, Gossypium hirsutum L., Delta Pine Smooth Leaf. An active fraction could be extracted from freeze-dehydrated bud powder with water after successive extractions with several less polar solvents and, consequently, after removeal of hydrocarbons, carotenoids, terpenoids, and flavonoids. The major active polar principle extractable with water was not absorbed on a weak cation exchange resion and was precipitated with lead ions. Studies by gel permeation suggested a moderate molecular

weight (<2000) for the active constituent(s) and eliminated proteins, large peptides, and polysaccharides with high molecular weights. Moderate feeding activity was found in methanol extracts of cotton buds in a fraction containing acidic components, but no active phenolic or carbosylic acid was isolated. Strong feeding activity was retained after fractions from methanol extracts were treated to remove or degrade flavonoid glycosides (and other glycosides), although 2 flavonoids with modest activity were isolated.

863. ; Frye, J.; Shealy, Y. F.; Hedin, P. A.; Thompson, A. C.; and Minyard, J. P. 1968. Constituents of the cotton bud. XI. Studies of a feeding-stimulant complex from flower petals for the boll weevil. J. Econ. Entomol. 61: 664-667.

Analogous extracts of the flowers and buds of cotton, Gossypium hirsutum L., were compared as feeding stimulants for the boll weevil, Anthonomus grandis Boheman. The flower extracts and their fractions were examined by paper, column, thin-layer, and gel-permeation chromatography and active fractions were obtained. A methanol-extractable active substance was concentrated by precipitation with lead acetate, and another highly active fraction was recovered by re-extraction with methanol. Examination of the acidic, ether-extractable components in methanol extracts of flowers and buds indicated that these fractions from buds were more stimulating than similar extracts of flowers.

864. Sukkestad, D. R.; Cardwell, D. L.; Pomonis, J. G.; and Nelson, D. R. 1972. Quantitative analysis of busulfan in boll weevils by gas chromatography. J. Econ. Entomol. 65: 353-356.

Recovery of busulfan (1,4-butanediol dimethanesulfonate) from Anthonomus grandis Boheman that had been injected or topically treated was determined

by liquid scintillation spectrometry and gas chromatography. Average recovery of labeled busulfan was 93% for bothe the topically treated and injected weevils. Average recovery of unlabeled busulfan was 97 and 96% for topically treated and injected weevils, respectively.

865. Sullivan, W. N.; Schechter, M. S.; Amyx, C. M.; and Crooks, E. Elliott. 1972. Gas-propelled aerosols and micronized dusts for control of insects in aircraft. 7. Effectiveness against pest insects of Agriculture. J. Econ. Entomol. 65: 1462-1466.

When adult boll weevils, Anthonomus grandis (Boheman); tobacco budworms, Heliothis virescens (F.); brown dog ticks, Rhipicephalus sanguineus (Latrielle); alfalfa weevils, Hypera postica (Gyllenhal); Japanese beetles, Popillia japonica Newman; European chafers, Amphimallon majalis (Razoumowsky); house crickets, Acheta domesticus (L.); bruchids, Zabrotes subfasciatus (Boheman); and vinegar flies, Drosophila melanogaster Meigen, were exposed to several promising micronized insecticidal dusts and insecticidal aerosols in tractor trailers, freight cars, and aircraft, excellent initial kills were obtained with Mobam® (benzo[b]thien-4-yl methylcarbamate), resmethrin, chlorpyrifos, and propoxur used alone and in combination. The residual effect varied somewhat depending on the species tested. The 2 most promising aerosols were concentrated preparations of resmethrin and d-trans allethrin.

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866. Taft, H. M. 1976. Problems in developing an insecticide for cotton insect control. Proc. 1976 Beltwide Cotton Prod. Res. Conf., pp. 131-132.

Problems in developing new insecticides from the field to industry and government are: experimental with plot identification and record keeping, changes in formulations, low priority assessment by the public and administrators, insufficient funding, and complying with EPA regulations. Some future problems and possible solutions are listed.

867. . 1978. Cotton: early tests with Dimilin on the boll weevil. Thompson-Hayward Chemical Co., Kansas City, MO. Special Issue-Breakthrough in Pest Control, P A-10-11.

The early history of the application of Dimilin to weevil control is traced from the discovery that it would prevent hatch of eggs from females exposed to it by contact, it's use in an invert sugar bait in a field test, and finally it's application in a non-phytotoxic crop oil.

868. , and Hopkins, A. R. 1966. A low-volume mist sprayer for applying insecticide concentrates from ground equipment. U.S. Agric. Res. Serv. [Rep.] ARS-33-109, 12 pp.

Ground equipment was needed that would disperse low-volume materials to protect cotton plants from insect pests. Using a Potts model no. P-48 mist blower mounted on a self-propelled sprayer chassis, equipped with Mini-Spin® nozzles and a sprayer pressure unit, produced a fine, atomized spray that effectively covered 10 rows. The greater number of droplets were deposited on the foliage on the leeward side of the swath. Field cage tests indicated that several formulations produced boll weevil mortality $\geq$98% after 48 h and several formulations produced bollworm mortality $\geq$78% after 96 h.

869. , and Hopkins, A. R. 1966. Effect of different hibernation environments on survival and movement of the boll weevil. J. Econ. Entomol. 59: 277-279.

Boll weevils, Anthonomus grandis (Boheman), collected from woods trash in the fall, were reinstalled in woods trash of different depths and moisture content. Treatments consisted of woods trash of 1, 3, 5, and 7 inches receiving normal rainfall of 14.6 inches, 3 inches of woods trash receiving no moisture, and 3 inches of woods trash receiving 14.6 inches of normal rainfall plus 12.5 inches additional moisture. Survival was greater in woods trash 3 inches deep with no moisture than in other environments provided. Only 1.2% of the weevils involved in the experiment moved from one environment to another.

870. , and Hopkins, A. R. 1967. Control of cotton pests with low-volume insecticides applied with a low-volume mist sprayer. J. Econ. Entomol. 60: 608-610.

Several insecticides were evaluated with ultra-low-volume (1-16 fl oz/acre), low volume (16 fl oz/acre), and conventional (1 gal/acre) ground spray equipment against the boll weevil, Anthonomus grandis Boheman; the bollworm, Heliothis zea (Boddie); the cotton aphid, Aphis gossypii Glover; and the carmine spider mite, Tetranychus telarius (L.). Malathion, methyl trithion, and carbaryl applied as technical materials, solutions, and suspensions showed promise of controlling cotton pests.

871. , and Hopkins, A. R. 1975. Boll weevils: field populations controlled by sterlizing emerging overwintered females with a TH-6040 sprayable bait. J. Econ. Entomol. 68: 551-554.

A sprayable invert sugar bait containing Thompson-Hayward TH-6040 (N-(4-chlorophenyl)-N'-(2, 6-difluorobenzoyl)urea) was applied in the field (as a coarse spray with maximum droplet size in the 3- to 4-mm-diam range) to sterilize female Anthonomus grandis Boheman. Weevil infestations were determined 3 times

weekly from June 14 to July 10. Adult emergence from all infested squares was reduced 98%. This experiment demonstrated that the field population of boll weevils was drastically suppressed by sterilizing the females so as to prevent the development of the F_1 generation.

872. , and Hopkins, A. R. 1977. A comparison of toxaphene + DDT + methyl parathion with presently recommended and experimental insecticides for control of cotton pests in South Carolina. Proc. 1977 Beltwide Cotton Prod. Res. Conf., pp. 147-148.

A field test comparing toxaphene + DDT, toxaphene + methyl parathion + chlordimeform, EPN + methyl parathion + chlordimeform, permethrin, fenvalerate, sulprofos + azinphosmethyl indicated equal control of Heliothis spp. and boll weevil Anthonomus grandis during early and mid-season. However, more effective late season control of Heliothis spp. and beet armyworms, Spodoptera exigua by the fenvalerate treatment resulted in greater yield from these plots when compared to the toxaphene + DDT + methyl parathion treated plots.

873. , and Hopkins, A. R. 1978. Boll weevils: effects of various numbers of Leggett traps on small and large populations. J. Econ. Entomol. 71: 598-600.

Neither a small nor a large population of Anthonomus grandis Boheman was suppressed by from 10-80 pheromone traps/ha though the optimum number of traps/ha (greatest number of weevils captured/trap) was determined to be 20 for a large population. The regression of square infestation on trap capture was best expressed by the equation $y = 0.09 + .048X$. During the 1st and 2nd week of trapping (prior to squaring), captures within the field were clumped and fit a negative binominal distribution. Eighty % of the total weevils were captured and 75% of the punctured squares were found in a 20-m-wide belt around a cotton field. Boll weevil pheromone traps therefore can function alone only as a survey and

detection tool; traps must be combined with other techniques when used in an integrated control program.

874. ; Hopkins, A. R.; and Agee, H. R. 1969. Response of overwintered boll weevils to reflected light, odor, and electromagnetic radiation. J. Econ. Entomol. 62: 419-424.

Overwintered adult Anthonomus grandis Boheman were studied to determine how they locate cotton when they leave hibernation sites. Attractant stimuli that might be produced by cotton that were examined were light, odor, or electrostatic field. The numbers of weevils responding to the stimuli indicated that weevils distinguish colors and respond in significantly greater numbers to wavelengths of light in the blue-green region (500-525 nanometers) than in others. They were not attracted by light in the red region of the spectrum (600-650 nanometers) or by the odor of cotton or cocklebur plants. There was an indication in 1 experiment that the weevils could detect differences between grounded and ungrounded plants.

875. ; Hopkins, A. R.; James, W.; and Moore, R. F., Jr. 1973. Boll weevils: time of entry into hibernation sites and variations in survival and emergence. J. Econ. Entomol. 66: 254-256.

A method of determining the time of entry of boll weevils, Anthonomus grandis Boheman into hibernation sites was devised. No relationship was found between the time weevils entered hibernation sites in the fall and the time they emerged in the spring. Surviving weevils lived from 4 to 127 days but the means from the 8 entry dates were not significantly different.

876. ; Hopkins, A. R.; Jernigan, C. E.; and Webb, J. C. 1969. A new 8-row ground sprayer with auxiliary air for ULV application of pesticides to cotton. J. Econ. Entomol. 62: 570-574.

A ground sprayer that uses the principle of the air blast to deliver ultra low

volume (ULV) applications of pesticides minimized drift and increased the amount of material deposited on the target area. The 8-row sprayer consists of 8 boom-mounted external atomizers (1 per row) that spray finely atomized material into air blasts of about 85 mph that are directed into the plants. The rapidly moving air replaces the carrier water used in a conventional water-oil emulsion sprayer. ULV applications of Azodrin® (3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate), technical grade Bay 41831 (O, O-dimethyl O-4nitro-m-tolyl phosphorothioate), and toxaphene + DDT were compared with conventional spray applications of toxaphene + DDT and Azodrin against various cotton pests. Results against the boll weevil, Anthonomus grandis Boheman; the bollworm, Heliothis zea (Boddie); and the carmine spider mite, Tetranychus cinnabarinus (Bosiduval), obtained with materials applied with the new ULV sprayer were at least as good as those obtained when the insecticides were applied with the conventional sprayer.

877. ; Hopkins, A. R.; and Roach, S. H. 1972. Suppression of emerging early-season boll weevils using integrated control. J. Econ. Entomol. 65: 1663-1666.

In 1968 and 1969, field experiments were conducted at Florence, South Carolina, against populations of emerging overwintered Anthonomus grandis Boheman. In 1968, complete suppression was not achieved with an integrated control program consisting of foliar sprays of toxaphene + DDT + methyl parathion, plus in-furrow and sidedress applications of aldicarb, but the population of overwintered boll weevils was reduced 57% below that resulting from foliar treatment alone. In 1969, one integrated program consisting of foliar sprays of toxaphene + DDT + methyl parathion plus the in-furrow and sidedress applications of aldicarb, and another consisting of the same treatments plus boll weevil pheromone traps, suppressed the population of emerging overwintered boll weevils.

878. Talmadge, K.; Albersheim, P.; and Earle, N. W. 1970. Cotton plant cell wall polysaccharide degrading enzymes of the boll weevil. J. Econ. Entomol. 63: 712-714.

The apparent participation of polysaccharide degrading enzymes in the nutrition of the boll weevil leads to some interesting questions. Most degradative enzymes of this type are inducible rather than constitutive; such inducible enzymes are synthesized only when required (Jacob and Monod 1961). It would be of value to learn what stages of the life cycle of the boll weevil possess these enzymes. If the enzymes are inducible, perhaps the induction can be interrupted. If these enzymes are required for normal growth and development of the boll weevil, it may be possible to prevent development of the insect by specifically repressing the synthesis of such digestive enzymes. Specific repression of the synthesis of the boll weevil's digestive enzymes should not adversely affect the cotton plant, since the plant is unlikely to require such enzymes for its own development.

879. Taylor, C. R.; and Lacewell, R. D. 1977. Boll weevil control strategies: regional benefits and costs. South. J. Agric. Econ. 1(July): 129-135.

Boll weevil control alternatives are being developed and proposed basically to benefit farmers. This analysis strongly suggests that in the aggregate, farmers in their role as landowners would not benefit from the programs. Rather, landowners would lose because land values would fall. Consumers of cotton however, would benefit through lower prices. Another major implication of this study is that eradication may not be the optimum boll weevil control alternative for either society or producer. The analysis suggests that an IPM alternative requiring some additional research, but that potentially could be put into practice in five to ten years, may have the largest potential. However, likely cost of acquiring these benefits needs to be carefully considered. A boll weevil IPM control alternative, which presently exists and could be put into practice within one year,

would provide social benefits of $332 million more than an eradication program. Thus, with this magnitude of difference between social benefits for IPM and eradication, very serious questions as to the economic feasibility of boll weevil eradication must be acknowledged. These results suggest that the estimates of change in yields and costs for the different boll weevil control strategies would have to be grossly inaccurate to change the basic solution and thus the recommendation to this report.

880. Temple, C., Jr.; Roberts, E. C.; Frye, J.; Struck, R. F.; Shealy, Y. F.; Thompson, A. C.; Minyard, J. P.; and Hedin, P. A. 1968. Constituents of the cotton bud. XIII. Further studies on a nonpolar feeding stimulant for the boll weevil. J. Econ. Entomol. 61: 1388-1393.

The nonpolar feeding stimulant complex for Anthonomus grandis Boheman found in the buds of cotton, Gossypium hirsutum L. (Deltapine Smooth Leaf), was fractionated and concentrated. Active fractions were extracted from buds and freeze-dehydrated bud powder with petroleum ether, chloroform, acetone, and chloroform-methanol. These fractions possessed widely different properties from those of the polar fractions studied previously. Silicic acid column chromatography produced a series of related compounds having the properties of the polar lipids. Thin-layer chromatography and countercurrent distribution studies produced compounds that were probably pheophytins. When pheophytins a and b were isolated from the bud, they gave high feeding activity after significant purification. Pheophytin a from spinach also gave modest activity, but cotton pheophytin a was inactive after hydrolysis and resterification with phytol. These and previous studies of the polar feeding-stimulant complex suggest that a multicomponent system is responsible for optimum feeding activity of the boll weevil.

881. Terranova, A. C. 1971. An automated procedure for analysis of busulfan in boll weevils and in fortified boll weevil diet. J. Econ. Entomol. 64: 549-550.

An AutoAnalyzer was used to analyze 1,4-butanediol dimethanesulfonate residues incorporated into boll weevils and into boll weevil diet as a rate of 20 samples per hour. Extraction procedures resulted in about 95% recovery of the chemical, and sensitivity as good as 0.5×10^{-4} moles/liter.

882. . 1980. Inheritance patterns of aldehyde oxidase, glutamate-oxaloacetate transaminase and phosphoglucomutase allozymes in the boll weevil. Ann. Entomol. Soc. Am. 73: 653-657.

The inheritance patterns of aldehyde oxidase (Ao), glutamate-oxaloacetate transaminase (Got), and phosphoglucomutase (Pgm) were investigated in the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae), with polyacrylamide gel electrophoresis. There are codominant autosomal alleles segregating at 4 loci. One Ao locus was unreliable as a marker under the conditions used. The remaining Ao locus and Got locus, both with 2 alleles, and Pgm locus, with 3 alleles, were easily scored and made useful markers. The heterozygotes of Ao and Got exhibited 3 bands, which suggests that the enzymes of these systems are dimers. Pgm heterozygotes exhibited only 2 bands, which suggests monomerin enzymes.

883. Terry, P. H.; Borkovec, A. B.; and McHaffey, D. G. 1972. Chemosterilants against the boll weevil. 3. Phosphorus amides. J. Econ. Entomol. 65: 1550-1552.

Of 56 nonalkylating phosphorus amides tested against Anthonomus grandis Boheman, 16 derivatives of phosphoric acid and 12 derivatives of phosphorothioic acid were effective in inhibiting oviposition. In comparison to 2 triamides of phosphoric acid, 2 triamides of phosphorothioic acid were the more toxic, but their sterilizing effectiveness was higher and more permanent.

884. ; McHaffey, D. G.; and Borkovec, A. B. 1977. Uptake and residues of chemosterilants in boll weevils treated by fumigation or dipping. J. Econ. Entomol. 70: 427-430.

Uptake and residues of hempa and thiotepa in Anthonomus grandis Boheman sterilized by vacuum fumigation, atmospheric fumigation, or vacuum dipping were determined. When comparable sterility was achieved in either type of fumigation treatment, the uptake of hempa was 10-100 times that of thiotepa. However, the uptake at atmospheric pressure was lower than that in the vacuum treatment. Thiotepa induced 99-100% sterility in all treatments but its uptake was lowest in the fumigation at atmospheric pressure. The uniformity of uptake by individual weevils was higher in the atmospheric fumigation than in the dipping. No residues of thiotepa were detected in treated weevils 4 days posttreatment but traces of hempa persisted for as long as 16 days posttreatment.

885. Texas Agricultural Experiment Station. 1969. Glasscock County, Texas, farmers unite fighting ole boll weevil. Tex. Agric. Prog. 15(1): 22-23.

Desire and a common goal are two necessary ingredients for effective group action. The farmers in Glassrock County can speak from experience on these two matters. They recognized their problem and decided to do something about it. A fall diapause control program with Guthion applied to 15,000 acres of cotton drastically reduced boll weevil numbers that entered hibernation sites and with winter mortality reduced infestations in the subsequent crop.

886. Thomas, B. R., and Wright, J. E. 1980. Titers of 20-hydroxyecdysone in boll weevil pupae. Southwest. Entomol. 5: 69-71.

Pupae of the boll weevil, Anthonomus grandis Boheman, were found to have a maximum of 20-hydroxyecdysone 48 hrs after the prepupal stage. No α-ecdysone was detected. A simplified high performance liquid chromatography (HPLC) method for analysis of ecdysones was developed.

887. Thomas, C. A., Jr., and Goddard, R. J. 1966. Low-volume concentrated sprays applied by ground equipment for control of the boll weevil. J. Econ. Entomol. 59: 114-116.

During 1964 low-volume concentrate spray was evaluated for control of the boll weevil, Anthonomus grandis Boheman. Technical malathion applied with ground equipment gave excellent weevil control. Commercially available nozzles (Spraying Systems 730023 or equivalent) were fitted to a high-clearance sprayer. With this system it was possible to apply 25 ounces of technical malathion (2 pounds) per acre. To apply smaller amounts of technical malathion with these nozzles, it was necessary to use water to make up the necessary volume. With sufficient agitation water and technical malathion will stay in suspension. When the water and malathion droplet strikes the cotton leaf the water evaporates leaving only the technical malathion. It is possible for this system to be adapted to existing sprayers with very few modifications.

888. Thompson, A. C.; Henson, R. D.; Gueldner, R. C.; and Hedin, P. A. 1972. Constituents of the boll weevil, Anthonomus grandis Boheman: III. Lipids and fatty acids of subcellular particles of pupae. Comp. Biochem. Physiol. 43B:883-890.

Phospholipids were the principal lipids in the microsomes, nuclei and mitochondria of the boll weevil, Anthonomus grandis Boheman. The major fatty acid in the phospholipids of the boll weevil was octadecadienoic acid (18:2) followed by octadecenoic acid (18:1) and hexadescanoic acid (16:0). The weight of neutral lipid varied in the subcellular particles, but the ratios of fatty acids remained the same. Phosphatidlyl choline predominated in the other subcellular particles of the boll weevil. Triglycerides made up about 50 percent of the neutral lipids of the nuclei, microsomes and cytoplasm. The principal neutral lipids of the cell mitochondria were diglycerides and monoglycerides.

889. ; Henson, R. D.; Gueldner, R. C.; and Hedin, P. A. 1973. Constituents of the boll weevil, Anthonomus grandis Boheman: VIII. Lipids and fatty acids in the subcellular particles of pharate pupae. Comp. Biochem. Physiol. 45B: 233-239.

1. Neutral lipids predominated in the nuclei and mitochondria fractions of pharate pupae of the boll weevil, Anthonomus grandis Boheman, and phospholipids predominated in the microsomes. 2. The nuclei and mitochondria lipids contained more linoleic (18:2) acid than the microsomes. 3. The decrease in 18:2 in the microsomes coincided with an increase in 18:3. 4. The average number of unsaturations per molecule of lipid was higher in the phospholipids than in the neutral lipids. 5. Phosphatidyl ethanolamine and phosphatidyl choline comprised 50-70% of all phospholipids in all subcellular components of pharate pupae. 6. Sterols and sterol derivatives were evenly distributed in the nuclei, mitochondria and microsomes of pharate pupae, pupae and adult stages of the boll weevil.

890. , and Leggett, J. E. 1978. Variation of lipid, protein and carbohydrate in over-wintered boll weevils, Anthonomus grandis Boheman. Comp. Biochem. Physiol. 60B: 201-203.

1. The neutral lipids decreased from 90 to 95% in male and female boll weevils, Anthonomus grandis Boheman, from May through July in the field. Neutral lipids were consistently higher (30-50%) in males than in females. 2. The wet weight and dry weight decreased 50 and 32%, respectively, from May through July. 3. The concentration of fatty acids in the polar lipids declined from 50 μg/mg dry wt in May to 10 μg/mg in the middle of June. 4. Protein and carbohydrate declined from 68 to 73% in the boll weevil from May through July.

891. , and McLaughlin, R. E. 1977. Comparison of the lipids and fatty acids of Mattesia grandis and the fat body of the host, Anthonomus grandis. J. Invertebr. Pathol. 30: 108-109.

The neogregarine, Mattesia grandis, infects larvae and adults of the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae) of the fatty acids from total lipids of the pathogen and host fat body are 16:00, 16:1, 18:00, 18:1, 18:2 and 18:3. Possibly 18:2 and 18:3 acids are essential to the pathogen, and depletion of these acids in fat body may limit growth. However, the requirement for polyunsaturated fatty acids does not appear to be the controlling factor in pathogen infection. It has been shown that 18:2 and 18:3 fatty acids comprise up to 33% of the total acids in the fat body of adult greater wax moth, Galleria mellonella, yet M. grandis will not infect this moth. Phosphatidyl choline (PC) comprises 73% of the total phospholipids in the pathogen compared with 41% in the host. Also, PC and phosphatidyl ethanolamine (PE) occur in about equal percentages in the adipose tissue of the host. It is not known whether the pathogen utilizes the phospholipids of the host intact or synthesizes its own. However, the host can obtain polyunsaturated fatty acids only by ingestion, and there is a direct competition for these compounds by the pathogen. Moreover, this competition is severe because of the extended development stages of the pathogen, which eventually utilizes all the adipose tissue of the host. Progressive utilization of the fatty acids by the pathogen and destruction of the fat body of the host impairs molting, pupation, ecdysis, and egg synthesis in the infected female boll weevil.

892. ; Pratt, J. R.; Minyard, J. P.; and Hedin, P. A. 1970. Constituents of the cotton bud. XVII. A survey of the lipids and fatty acids of glanded and glandless cotton with respect to nutrition and host-preference of the boll weevil. J. Econ. Entomol. 63: 753-756.

Lipid extracts of 'Acala' 4-42-77 and 'Rex Smoothleaf' and of their isogenic

lines caused similar feeding responses in Anthonomus grandis Boheman, in the rolled plug assay. The total fatty acids in the glanded and glandless lines did not vary significantly, but the phospholipids and glycolipids of glanded lines contained 50% more fatty acids than did those of the glandless lines. This difference resulted primarily from differences in the amounts of unsaturated fatty acids, linolenic acid ($C_{18:2}$). About 50% of the total fatty acids in the glandless lines were contained in a highly polar lipid complex that was removed from silicic acid by hydrolysis with an acid solution.

893. , and Mitlin, N. 1979. Biosynthesis of the sex pheromone of the male boll weevil from monoterpene precursors. Insect Biochem. 9: 293-294.

Biosynthesis of the four monoterpene compounds that comprise the sex pheromone of the male boll weevil, Anthonomus grandis, was demonstrated by using a mixture of geraniol and nerol. An average 2.4% of the administered radioactive alcohols was incorporated into the pheromone components. The amount of radioactivity incorporated into each pheromone component indicated that these two isomeric alcohols are incorporated directly into the pheromone biosynthetic pathway.

894. , and Scott, W. P. 1979. Lipids, proteins and carbohydrates in overwintered boll weevils, Anthonomus grandis Boheman, from woods trash. Comp. Biochem. Physiol. 62B: 155-157.

1. The dry weight of diapausing boll weevils increased from 26 to 68% from November to March. 2. The concentration of fatty acids in the neutral lipids averaged 130.2 ± 19.6 μg/mg dry weight. The total fatty acids declined to 50.0 ± 1 μg/mg dry weight over the period studied. 3. The concentration of fatty acids in the polar lipids averaged 5.6 ± 1.6 μg/mg dry weight; the range was 15.3-1.0 μg/mg dry weight. 4. The average concentrations for protein and for carbohydrate were 337.0 ± 62.1 and 64.8 μg/mg dry weight, respectively.

895. , and Sikorowski, P. P. 1978. The effect of bacterial load on amino acids in the boll weevil, Anthonomus grandis. J. Invertebr. Pathol. 31: 388-389.

The concentrations of each amino acid is the average of 10 replicates of five weevils each. The bacterial count for contaminated weevils was 5000 and above. Individual amino acids were in greater concentration in the uncontaminated female than in the uncontaminated male by 10 to 15%. However, the average total loss of amino acids due to bacterial contamination was 18% in the females and 22% in the male weevils. The amount of serine and lysine was not greatly affected by bacterial contamination in the female, whereas the concentration of tryosine doubled. Others have shown that weevils with 2.2×10^5 bacteria in the gut produced 0.59 μg of pheromone/weevil per day; weevils with 1.4×10^3 bacteria produced 3.51 μg. We do not know whether the decrease in amino acids of contaminated weevils occurs because of competition by bacteria for acids in the diet or whether the contaminated insects lose the ability to absorb amino acids and protein through the cell wall of the midgut.

896. ; Sikorowski, P. P.; and Wyatt, J. M. 1977. The effect of bacterial load on fatty acids in the boll weevil, Anthonomus grandis (Coleoptera: Curculionidae). J. Invertebr. Pathol. 30: 274-275.

The concentration of each fatty acid found (16:0, 16:1, 18:0, 18:1, 18:2) was converted to calories for three levels of bacterial contamination. Comparison of individual fatty acids from the contaminated and uncontaminated showed a decrease up to 76% in the highly contaminated (5000 + bacteria/weevil) weevils. Caloric evaluation of the fatty acids in the boll weevil egg indicated that the healthy female must provide 25.1% of her total body fatty acids per day in producing eggs (seven eggs/day). The presence of these bacteria can, therefore, place a stress on oviposition.

897. ; Wright, B. J.; Hardee, D. D.; Gueldner, R. C.; and Hedin, P. A. 1970. Constituents of the cotton bud. XVI. The attractancy response of the boll weevil to the essential oils of a group of host and nonhost plants. J. Econ. Entomol. 63: 751-753.

When the essential oils of several host and nonhost species within the Malvaceae family and some angiosperms and gymnosperms were tested for attractancy to Anthonomus grandis Boheman, the oils were as attractive as cotton oil. Moreover, the insect actually favored essential oils of 2 alternate host plants, Hibiscus militaris Cav. and H. lasiocarpus Cav., in comparative preference tests with cotton oil. Thus, in the laboratory, the essential oils in plants did not control insect preference exclusively. Morphological and environmental conditions may influence the concentrations of volatile components released by the plants to the atmosphere.

898. Timmons, F. D.; Brook, T. S.; and Harris, F. A. 1973. Effects of aldicarb applied side-dress to cotton on some arthropods in the Monroe County, Mississippi, boll weevil diapause-control area in 1969. J. Econ. Entomol. 66: 515-153.

The effects of aldicarb on boll weevils, Anthonomus grandis Boheman; Heliothis larvae; and beneficial predators was investigated in large fields of cotton with and without boll weevil sex-attractant traps. Three of the fields in the Monroe County, Miss., boll weevil diapause-control area had boll weevil sex-attractant traps, and with 1 lb (0.9 kg) active ingredient of aldicarb applied as a side-dress application to cotton in the pin-head square acreage, season-long boll weevil control was obtained. Three aldicarb-treated fields without boll weevil sex-attractant traps had 39 days of boll weevil control, Heliothis larvae became an economic problem earlier in the aldicarb-treated fields than in the control fields. Predator reduction was drastic in the aldicarb-treated fields after the first rain. The predator population generally increased in the control fields until they were

treated for control of Heliothis larvae or boll weevils later in the season.

899. Tingle, F. C.; Lane, H. C.; King, E. E.; and Lloyd, E. P. 1971. Influence of nutrients in the adult diet on diapause in the boll weevil. J. Econ. Entomol. 64: 812-814.

The ratio of proteins and carbohydrates in the adult diet of Anthonomus grandis Boheman was varied to study its effect on the initiation of diapause. Removal of germinated cottonseed puree from the standard diet greatly increased the incidence of diapause, but this effect was offset partially by increasing the level of protein and decreasing the level of sucrose. Similarly, a reduction of protein and an increase in sucrose caused greater numbers of insects to enter diapause. We were not able to extract the component(s) of germinated cottonseed that prevent initiation of diapause with chloroform, acetone, water, and dilute NaOH, in succession. A cottonseed flour or the alkali-soluble protein of that flour was equal to or better than germinated cottonseed in preventing the initiation of diapause.

900. , and Lloyd, E. P. 1969. Influence of temperature and diet on attainment of firm diapause in the boll weevil. J. Econ. Entomol. 62: 596-599.

When maximum fat and minimum moisture content were used as criteria, adult Anthonomus grandis Boheman fed 11- to 15-day-old bolls and held at 26.7°C attained firm diapause in 1 week; when the temperature was 21.1°C during a 10-hr light period and 10°C during a 14-hr dark period, the weevils took 3-4 weeks to attain maximum fat and minimum moisture. Thus, time required for these adult weevils to attain firm diapause was adversely related to temperature. However, the weevils held at 26.7°C and fed 11- to 15-day-old bolls attained firm diapause more rapidly than those fed 1- to 10-day-old bolls or squares, and the diet did not influence the time to firm diapause when the weevils were held at the lower temperatures.

901. Traas, P. C.; Boelens, H.; and Takken, H. J. 1976. Convenient synthesis of 3,3-dimethylcyclohexylideneacetaldehyde, a sex attractant of the male boll weevil. Synth. Commun. 6: 489-493.

In a previous communication we reported on the synthesis of 3,3-dimethylcyclohexylideneacetaldehyde, an important component of the sex pheromone complex of the male boll weevil. A key step in this synthesis involved the simultaneous removal of halogen and a double bond from an intermediate poly unsaturated aldehyde by selective reduction. As a part of our investigations on the Vilsmeier formylation of vinylcyclopropanes and dienes[2], we have found an easy route to aldehyde, and we now show that this aldehyde can serve as an excellent synthon for the preparation of 3,3-dimethylcyclohexylideneacetaldehyde.

902. Trost, B. M.; Keeley, D. E.; Arndt, H. C.; and Bogdanowicz, M. J. 1977. New synthetic reactions, synthesis of cyclobutanes, cyclobutenes, and cyclobutanones. Applications in geminal alkylation. J. Am. Chem. Soc. 99: 3088-3100.

The chemistry of the adducts of 1-lithiocyclopropyl phenyl sulfide to aldehydes and ketones is reported. Treatment of these compounds with p-toluenesulfonic acid under anhydrous conditions or the Burgess reagent yields 1-phenylthiocyclobutenes, which may be hydrolyzed to cyclobutanones, desulfurized to cyclobutanes, or thermalized to dienes. Rearrangement to cyclobutanones can be achieved under four sets of conditions: (1) aqueous fluoboric acid-ether, (2) stannic chloride-methylene chloride, (3) p-toluenesulfonic acid in benzene saturated with water, and (4) Meerwein's reagent. Alternatively, the O-phenylene phosphite ester of these alcohols, generated by directly quenching the reaction of 1-lithiocyclopropyl phenyl sulfide and the carbonyl compound with O-phenylene phosphorochlorodite, rearranges to the cyclobutanone in refluxing aqueous THF in the presence of an acid catalyst. The stereochemistry of this arrangement is delineated and complements that obtained by the cyclobutanone annelation with dephenylsulfonium cyclopropylide. The approach allows

cyclobutanes, cyclobutenes, and cyclobutanones to be generated from both saturated and α,β-unsaturated carbonyl partners. Application of this approach for geminal alkylation to the total synthesis of the constituent of the sex pheromone of the boll weevil, grandisol, is reported.

903. Tumlinson, J. H.; Gueldner, R. C.; Hardee, D. D.; Thompson, A. C.; Hedin, P. A.; and Minyard, J. P. 1970. The boll weevil sex attractant. In Morton Beroza (ed.), Chemicals Controlling Insect Behavior pp. 41-59, Acad. Press, NY.

The isolation and identification of four terpenoid compounds from the male boll weevil, which, when properly combined, attract the female, are reported. The structures of all four have been confirmed by synthesis and each is biologically active. The active compounds were isolated from both fecal material and insects by steam distillation and a series of chromatographic separations. They were identified, on the basis of chemical and spectral evidence, as: (I), cis-2-isopropenyl-1-methylcyclobutaneethanol; (II), cis-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol; (III), cis-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde; (IV), trans-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde. These compounds were present in fecal material in concentrations of 0.76, 0.57, 0.06, and 0.06 ppm, respectively. Compounds (I)-(IV) have been synthesized the the synthetic compounds are equally as attractive as the natural substances to females. To produce a substance attractive to females in laboratory bioassays it was necessary to combine compounds (I), (II), and either (III) or (IV). Absence of either of the alcohols or both of the aldehydes resulted in an inactive mixture.

904. ; Gueldner, R. C.; Hardee, D. D.; Thompson, A. C.; Hedin, P. A.; and Minyard, J. P. 1971. Identification and synthesis of the four compounds comprising the boll weevil sex attractant. J. Org. Chem. 36: 2616-2619.

Four terpenoid compounds, (+)-cis-2-isopropenyl-1-methylcyclobutaneethanol, (1),

Z-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneethanol (2), Z-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (3), and E-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (4), were identified as the components of the male sex pheromone of the boll weevil. The synthesis and structural assignments of the four compounds are also reported.

905. ; Hardee, D. D.; Gueldner, R. C.; Thompson, A. C.; and Minyard, J. P. 1969. Sex pheromones produced by male boll weevil: isolation, identification, and synthesis. Science 166: 1010-1012.

The response of female boll weevils to males, Anthonomus grandis Boheman, in laboratory bioassays can be reproduced by exposure to a mixture of compounds I, II, and either III or IV, all isolated from male weevils and their fecal material. The same response was elicited by mixtures of the synthesized compounds. Compound I is (+)-cis-2-isopropenyl-1-methylcyclobutaneethanol; II, cis-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol; III, cis-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde; and IV, trans-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde.

906. ; Hardee, D. D.; Minyard, J. P.; Thompson, A. C.; Gast, R. T.; and Hedin, P. A. 1968. Boll weevil sex attractant: isolation studies. J. Econ. Entomol. 61: 470-474.

Techniques for isolating the sex attractant of the boll weevil Anthonomus grandis Boheman, were studied. Aeration of live insects, extraction procedures, column chromatography on Florisil® and Carbowax 20M® coated silica gel, and steam distillation of male and mixed weevils and of fecal material are described. Bioassays of the fractions obtained indicated that steam distillation of male or mixed insects or fecal material is the preferred method of isolating the attractant.

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907. U. S. Agricultural Research Servicd. 1966-1980. Annual conference report on cotton-insect research and control, 19th-33rd. (ISSN 0098-0196.) The Service, Washington, D.C. [Publisher and place of publication vary: 32nd and 33rd published by U.S. Science and Education Administration, 30th-33rd published in New Orleans.]

Preceding report revised to include latest information on insecticides or other control techniques that have been developed for practical use in controlling cotton insects. Publication provides research, extension and other entomologists, cotton growers, chemical and cotton industries with latest available information on control of cotton insects and has status as the "Cotton insects bible" of the world.

908. . 1968. 1000-year-old boll weevil. Agric. Res. 17(4): 10.

Cotton fragments from a Mexican cave have added a thousand years to the history of the boll weevil. ARS botanist, C. E. Smith, Jr., obtained the cotton fragment from an archeological excavation in Oaxaca Mexico, but credits discovery of the weevil to S. G. Stephens, Professor of Plant Evolution, at North Carolina State University who found the insect within an empty seed hull while examining cotton fragments he had obtained from Smith. The boll weevil was identified by ARS entomologist, R. E. Warner. Archeologist K. V. Flannery dated the fragments at AD 900 with the carbon 14 dating technique.

909. . 1969. Caged weevils sharpen detection tools. Agric. Res. 17(10): 14.

Sticky traps baited with live male boll weevils look promising for detection, survey, and possibly control of this cotton pest. Male boll weevils give off an attractant that is equally effective in luring both male and female weevils. Insects attracted to baited traps become entangled in the sticky coating and die. The traps have the best immediate potential as a survey and detection

tool to provide a more accurate early warning of potential infestations. They, also, show promise as a control device, particularly in newly infested areas or where control programs hold down weevils to less than 10 per acre.

910. . 1969. Male signals draw weevils to cotton fields. Agric. Res. 17(7): 6.

Boll weevils are drawn to cotton more by male weevils than by any attractant the plant itself may have. This recent research finding suggests that traps baited with male weevils, or with a male attractant (pheromone) yet to be isolated, may help in detecting and suppressing infestations.

911. 1969. Operation boll weevil. Trapping that 1 percent. Agric. Res. 18(4): 8-9.

The large-scale field trial is underway in the Texas High Plains by ARS research and regulatory entomologists, the Texas Department of Agriculture, Plains Cotton Growers, Inc., the Cotton Producers Institute, and the Texas Agricultural Experiment Station. The trial area covers about 1,800 square miles where some 40,000 acres of cotton are grown each year. The boll weevil invaded this area about 6 years ago but has been kept under economic control through a cooperative spray program, which reduced the weevil population by about 99 percent each fall. It is all but impossible, however, to find and kill the few weevils that manage to survive the winter. These weevils mate and start rebuilding the population. The special trapping effort has materially reduced the boll weevil population. As of August 10, only a few fields representing less than 5 percent of the trapping zone's cotton acreage were lightly infested. But 5 miles beyond the trapping zone, the cotton fields were virtually 100-percent infested.

912. . 1970. Isolated at last--the boll weevil's grandlure. Agric. Res. 18(11): 3.

Scientists stationed at the ARS Boll Weevil Research Laboratory, State College, Miss., have isolated four compounds, two alcohols and two adehydes, from boll weevils, which when mixed together produce an active synthetic attractant they named grandlure. In laboratory tests, females responded to grandlure in the same way that they reacted to live male boll weevils.

913. . 1971. Bracts--foil boll weevils. Agric. Res. 20(6): 3-4.

Frego bract, an odd cotton mutant, may have one of the keys to biological control of the weevil. Frego has unusually narrow twisted bracts which are not suited to the weevil's egg-laying habits. In normal cotton, the bracts are broad and leaflike, offering the weevil a preferred environment for egg-laying. Bracts are box like structures surrounding the buds. In 1970, ARS entomologists grew several 10- to 20-acre fields of Frego bract cotton on four forms in different parts of Mississippi. Their studies showed that frego bract reduced the boll weevil infestation 66 to 94 percent when compared to fields of nonfrego cotton.

914. . 1971. Found: chemosterilant for boll weevils. Agric. Res. 29(5): 5.

Busulfan, one of hundreds of chemical compounds tested, has been found to make male boll weevils sexually sterile with little or no damage to the weevil. One of the major advantages of busulfan is its permanent effect on males; other tested compounds induce only temporary sterility. Busulfan also results in little damage to the digestive system - a cause of premature death in weevils exposed to irradiation. Credit for developing busulfan as a sterilant is shared by a team of ARS chemists and entomologists.

915. . 1972. A better boll weevil trap. Agric. Res. 20(10): 11.
A new inexpensive trap for boll weevils captured twice as many of these cotton pests as did standard sticky traps in several test locations. Designated the Leggett trap after is principal designer Joseph E. Leggett, the trap adapts a paper mache liner used for cut flowers and is painted a bright yellow to attract boll weevils from the field. Live, caged weevils or grandlure, a synthetic sex attractant, placed at the narrow end of the cone lure the pests into a plastic or screen cage. The insects can then be collected or killed by a small amount of insecticide.

916. . 1974. Boll weevil sterility. Agric. Res. 23(5): 15.
A simple behavioral test has helped to determine quickly and accurately the degree of sterility in laboratory reared male boll weevils. Locomotion as a measure of vigor can predict the efficiency of the chemosterilant busulfan. The more physically active the weevils are, the less sterile they are judged to be. The locomotor test developed by ARS research entomologist was used successfully during the 1973 phase of the Pilot Boll Weevil Eradication Experiment.

917. . 1974. Nematode [sic] parasitized boll weevil. Agric. Res. 22(8): 11.
A new genus of a nematode that parasitizes the boll weevil has been found for the first time in North America. A natural enemy of the boll weevil, it is a wormlike parasite which penetrates the body cavity of the insect and kills it. The nematode causes the weevil to emerge from hibernation sites abnormally early. Especially hungry because the parasites have depleted their stored fat, the weevils invade the cotton fields in late March, 4 to 6 weeks before the cotton is planted. Finding no cotton, they die, meanwhile releasing the female nematodes in the soil to infest later generations of weevils.

918. . 1975. Curbing boll weevil egg hatch. Agric. Res. 24(5): 7.
Eradicating the boll weevil may be made easier with a new growth inhabiting urea-type chemical compounds, TH 6040, used in sprayable oil or other formulations that aid absorption by contact or feeding. In studies in ARS laboratories at Mississippi State, MS and Florence, SC, TH 6040 shows promise by acting as a female weevil sterilant in both laboratory and preliminary field tests. Actually, it is not a sterilant but inhibits insect development. It does not cause mutation, has very low mammalian toxicity, does not appear to accumulate in the food chain and prevents hatch of boll weevil eggs.

919. . 1975. Super-male boll weevils. Agric. Res. 24(4): 11.
If a male weevil is not naturally a "super" pheromone producer he can be made that way. Researchers added grandlure-impregnated paint to the insects' elytra, the protective wing covers which shield the functional wings. Small dots of "butyrate dope" containing grandlure placed on the weevils significantly increased the attractiveness of sterile males to females.

920. U.S. Department of Agriculture. 1969. The boll weevil . . . how to control it. U.S. Dep. Agric. Farmers Bull. 2147, 11 pp.
This is a revision of the Bulletin that was issued in 1962. The insecticides, formulations and rates to be used are given on one table. Azodrin, EPN, and Methyl Trithion have been added to the table. The following cautionary statement was added: "The registrations for use of azodrin, endrin, methyl parathion and Methyl Trithion on cotton were at the time of publication subject to cancellation on January 1, 1970. Do not use any of these insecticides on cotton after January 1, 1970, without first determining whether the registration remains effective. Check with your County Agricultural Agent or with your State Agricultural Experiment Station."

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921. Van den Bosch, R. 1971. The melancholy addiction of ol King Cotton. Nat. Hist. 80(10): 86-90.

The history of cotton insect control has been marked by waste, misery, death, and destruction. Yet we seem to have learned little from this pattern of disaster. The growers and entomologists of Central America, northeastern Mexico, and the Rio Grande and Imperial valleys apparently did not learn much from the experience of the Canete Valley. Now in Australia a newly developing cotton industry seems to be repeating the same mistake. The Australians have spread an insecticidal blanket and already the symptoms of the treadmill are beginning to appear.

922. Vanderzant, E. S. 1967. Wheat-germ diets for insects: rearing the boll weevil and the salt-marsh caterpillar. Ann. Entomol. Soc. Am. 60: 1062-1066.

The use of wheat-germ diets for insects is reviewed. Modification of these diets and nutritional experiments conducted with them are discussed. Larvae of the boll weevil, Anthonomus grandis Boheman, developed to adults on wheat-germ diet if cholesterol was included in the diet. Oviposition of boll weevil adults in wheat-germ diet was similar to that in germinated cottonseed diet. Moths of the salt-marsh caterpillar, Estigmene acrea (Drury), reared on wheat-germ diet and on casein diet containing corn oil, had deformed wings. However, when linolenic acid was added to the casein diet, the moths emerged with normal wings, an indication that this insect has a dietary requirement for linolenic acid. Linseed oil was used as a source of linolenic acid in the wheat-germ diet. Because wheat-germ diet was shown to be deficient in sterol and linolenic acid for certain species, quantitative requirements for these nutrients should be investigated when other species are reared on wheat-germ-based diets.

923. . 1973. Axenic rearing of larvae and adults of the boll weevil on defined diets: additional tests with amino acids and vitamins. Ann. Entomol. Soc. Am. 66: 1184-1186.

Studies of the requirements of Anthonomus grandis Boheman for the indispensable amino acids were extended. Semiquantitative requirements for histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine were established for weevils grown on an amino acid diet that had proved satisfactory previously. Tryrosine neither replaced nor spared phenylalanine when it was substituted for all or part of the phenylalanine. The boll weevil was found to require dietary biotin when it was fed an amino acid diet, but no requirement for vitamin B_{12} was observed for a single generation. Four generations of boll weevils were reared under aseptic conditions when both larvae and adults were fed a sterile defined diet.

924. . 1974. Development, significance and application of artificial diets for insects. Annu. Rev. Entomol. 19: 139-160.

Artificial diets were first developed for insects that could easily be maintained in the laboratory on natural foods. The insects' food was replaced with substances of known nutrient quality as the nutrients for animals were discovered. The, diets of known composition, designated as defined diets, were used to determine the nutrient requirements of insects. Practical diets could be made by combining unrefined materials with known nutrient supplements. Diets are now widely used for laboratory rearing and many are being used successfully for the mass production of insects. In recent years, many species of plant-feeding insects have been reared, and diets for several parasites and predators and have been used successfully. Laboratory rearing of insects has made it possible to study not only their nutrition but also their biochemistry, behavior, and other biological processes. Mass production of insects has provided a large supply for studies in methods of con-

trol of pests; release of parasites, predators and viruses; release of sexually sterile insects; and identification of attractants, hormones, and other biologically active compounds that occur in such trace amounts that large numbers of insects are needed for study.

925. , and Chremos, J. H. 1971. Dietary requirement of the boll weevil for arginine and the effect of arginine analogues on growth and on the composition of the body amino acids. J. Econ. Entomol. 64: 480-485.

Quantitative dietary requirements of the boll weevil, Anthonomus grandis Boheman, for arginine were determined by feeding an amino acid diet containing different amounts of arginine. Citruline produced good growth and development when it was substituted for arginine, but no growth occurred when ornithine was substituted. Canavanine was toxic and inhibited growth of the boll weevil. This toxic effect could be partially reversed by arginine. Homoarginine did not appear to be toxic, and, when combined with arginine, it alleviated the toxicity of canavanine. A method is described for the qualitative analysis of the amino acids in boll weevils by thin-layer chromatography. The contents of free and protein-bound amino acids were determined in weevils fed several rearing diets and in those fed diets containing analogues. Canavanine was not found in eggs and adults of boll weevils fed larval or adult diets containing this analogue. Homoarginine was found in the free amino acids of all samples, but not the protein.

926. Vavra, J., and McLaughlin, R. E. 1970. The fine structure of some developmental stages of Mattesia grandis McLaughlin (Sporozoa, Neogregarinida), a parasite of the boll weevil Anthonomus grandis Boheman. J. Protozool. 17: 483-496.

Sporozoites, macronuclear schizonts, merozoites and gamonts of Mattesia grandis were examined by electron microscopy. A conoidal complex, consisting of conoid,

polar rings and subpellicular microtubules was present in all of these stages. The conoidal complex was similar in structure to the same organelle of other Sporozoa. The conoidal complex in mono- to quadrinucleate macronuclear schizonts is transformed into an organelle similar to the mucron of some eugregarine. This mucron consists of a specialized area of the cell membrane from which fine fibers extend into a large vacuole situated directly beneath the cell membrane. The top part of the vacuole is encircled by 2 ring-like structures formed by the dilatation of the original apical rings. The vacuole of the mucron contains many anastomosing protrusions of the cytoplasm, suggesting a nutritional role. The mucron disappears when the schizont reaches the multinucleate state. Later the merozoites bud from the surface of the schizont as in the coccidia. Each merozoite again has a conoidal complex, which persists thru the gamont stage and usually serves as the point of contact between 2 gamonts during their pairing. The presence of a conoidal complex thru a major portion of the life cycle, its transformation into a mucron and the mode of formation of merozoites indicate that the Neogregarinida combine the fine structure characters of both the Eugregarinida and the Eucoccida, thereby suggesting a phylogenetic relationship between these sporozoans, with the neogregarines as a link between eugregarines and coccidia.

927. Vickers, D. H., and Mitlin, N. 1966. Changes in nucleic acid content of the boll weevil Anthonomus grandis Boheman during its development. Physiol. Zool. 39: 70-76.

The amounts of DNA and RNA present in the boll weevil, Anthonomus grandis Boheman, followed its growth-curve very closely. Maximum quantities and wet weight were attained late in the fourth larval instar. RNA was synthesized during the latter half of the pupal stage at the expense of the tissues. After emergence the amount of DNA was greater in males, but the amount of RNA was greater in females.

These differences were attributed to differences in quality and quantity of gametes produced by the two sexes.

928. Vig, O. P.; Sharma, S. D.; Bari, S. S.; and Kumar, S. D. 1977. Terpenoids: CXXVIII. Synthesis of 7-methyl-3-methylene-6-octen-1-ol (γ-Geraniol). Indian. J. Chem. 15: 93-94.

Treatment of 7-methyl-3-oxo-6-octen-1-ol (II) with dihydropyran and HCl affords the pyranyl ether (III) which on Wittig reaction with methylenetriphenylphosphorane yields 7-methyl-3-methylene-1-(tetrahydro-2'-pyranyloxy)-6-octene (IV). IV on treatment with PTS furnishes the title compound.

929. Villavaso, E. J. 1974. Artificial insemination of the boll weevil. Ann. Entomol. Soc. Am. 67: 825-827.

When the boll weevil, Anthonomus grandis Boheman, was artificially inseminated by a new technique, fertile eggs were obtained from 68.7% of the females; however, the number that laid fertile eggs dropped quickly over a 2-week period. Not as many spermatozoa reached the spermathecae of artificially inseminated females, and the spermatozoa were apparently not as active as those of normally inseminated females. The presence of active spermatozoa in the copulatory pouch stimulated egg production and normal oviposition behavior. The behavior of females artificially inseminated with only male accessory gland material was indistinguishable from that of virgin females.

930. . 1975. Functions of the spermathecal muscle of the boll weevil, Anthonomus grandis. J. Insect Physiol. 21: 1275-1278.

In female boll weevils, Anthonomus grandis, spermathecal filling was not affected by severing the spermathecal muscles. Females whose spermathecal muscles were severed 2 to 4 weeks after mating laid infertile eggs and resumed virginal ovipositional behavior indicating the importance of this muscle in supplying sperm for egg fertilization. The presence of normal active sperm within the

spermatheca in no way influenced ovipositional behavior. In females whose spermathecal muscles had been severed, 22 percent sperm displacement occurred after a second mating compared with 66 percent for normal females. The physical displacement of sperm was thus largely dependent on a functional spermathecal muscle.

931. . 1975. The role of the spermathecal gland of the boll weevil, Anthonomus grandis. J. Insect Physiol. 21: 1457-1462.

Spermatozoa were relatively inactive and did not enter the spermatheca of female boll weevils, Anthonomus grandis, whose spermathecal glands were removed as teneral adults. However, these females were able to lay fertile eggs for a 2 week period. When the spermathecal gland was removed from older females, spermathecal filling occurred, and although the spermatozoa retained their fertilizing capacity for extended periods, spermathecal emptying did not occur. Spermatozoa gradually lost their motility and fertilizing capacity, indicating that spermathecal secretions are effective in very small amounts. Spermatozoa were not activated by any of the materials contained in the normal male ejaculate. These materials alone did not effect spermathecal filling nor were they capable of maintaining the fertilizing capacity of the spermatozoa for very long. Sperm economy is low with less than 1 fertile egg laid per 100 spermatozoa used.

932. . 1976. Dark-scale: a recessive sex-linked mutant of the boll weevil. J. Hered. 67: 85-86.

A new mutant of the boll weevil is described. This mutant, designated dark-scale, is a sex-linked recessive carried on the X chromosome that affects coloration of the scales on the dorsal surface of the body (elytra and pronotum). Dark-scaled weevils are easily distinguishable with the naked eye from wild-type, light-scaled weevils. Crosses between dark-scaled females

and light-scaled males produce all dark-scaled F_1 males and all light-scaled F_1 females. This mutant may prove useful in the sex-separation phase of the prolonged boll weevil eradication program, especially if it allows mechanical separation of the sexes. The mutant may also be useful in isolating induced mutations such as male sterility, temperature sensitivity, etc.

933. . 1978. Boll weevils: increasing egg hatch and progeny development by the addition of antibiotics to the artificial adult diet. J. Ga. Entomol. Soc. 13: 173-177.

When the antibiotics penicillin and streptomycin were added to an artificial adult diet for the boll weevil, Anthonomus grandis Boheman, egg hatch and progeny development increased significantly. These increases apparently resulted from the elimination of bacterial slime from the adult diet. Egg production was not affected.

934. , and Earle, N. W. 1974. Attraction of female boll weevils to diapausing and reproducing males. J. Econ. Entomol. 67: 171-172.

In field trapping tests, reproducing males of Anthonomus grandis Boheman were twice as attractive as males in diapause, and the attractiveness of diapausing males did not differ from that of unbaited traps. Frass from reproducing males was 4X more attractive than frass from diapausing males in olfactometer tests. However, the increased incidence of pheromone deficient diapausing weevils in field populations in the fall does not clearly explain the renewed efficiency of pheromone traps during this period.

935. , and Earle, N. W. 1975. Response of virgin vs. mated and sterile vs. fertile female boll weevils to male-baited traps. Environ. Entomol. 4: 566-568.

In field cage and isolated field tests the response of virgin female boll weevils, Anthonomus grandis Boheman, to male-baited traps was from 2 to 9

times greater than that of mated females. Females that had mated as long as 1 wk prior to release were still not as responsive as were virgins. The interval after the last mating may be important in determining whether or not a mated female will remate. Response of mated females is also influenced by male density. The fact that some mated native females will respond to males a second time should be beneficial to a boll weevil eradication program. In field cage tests the response of sterile female boll weevils to male-baited traps was approximately the same as that of fertile females. If eradication of the boll weevil is attempted, the release of sterile females along with the sterile males may contribute the premature sperm depletion of the sterile males, unless an effective pheromone trapping systems is devised to remove these females from the field after release.

936. , and Earle, N. W. 1976. Competitiveness of busulfan-fed sterile vs. native male boll weevils. Environ. Entomol. 5: 279-280.

Field cage tests to evaluate the competitiveness between busulfan-fed sterile males of a laboratory strain and fertile males of a field-collected strain were conducted. The field-collected males mated with 66.2% of the released field-collected females and the sterile males mated with 27.0%; 6.8% of the females had apparently mated with both sterile and fertile males.

937. ; Earle, N. W.; and Hollier, D. D. 1977. Boll weevils: field and laboratory assessment of mating ability and sperm content after irradiation with or without diflubenzuron treatment. J. Econ. Entomol. 70: 562-564.

Sperm depletion did not occur within the 1st week after irradiated males and females of Anthonomus grandis Boheman were released together into isolated field plots. Also, survival and mating ability did not differ as a result of treatment. The treatments were: irradiation of 4-day-old adults plus di-

flubenzuron (N-(4-chlorophenyl)-N^1-(2,6-difluorobenzoyl) urea), fractionated irradiation of pupae, and fractionated irradiation of adults plus diflubenzuron.

938. ; Lloyd, E. P.; Lue, P. S.; and Wright, J. E. 1980. Boll weevils: competitiveness of sterile males in isolated field plots. J. Econ. Entomol. 73: 213-217.

In Louisiana and in North Carolina, isolated 0.2 ha cotton plots were used to evaluate the competitiveness of male Anthonomus grandis grandis Boheman sterilized by one of 3 treatment methods: fumigation for 90 min with bisazir (P, P-bis(1-aziridinyl)-N-methylphosphinothiotic amide) at atmospheric pressure, followed 30 min later by a 5 sec dip in a 1.35% solution of penfluron (2, 6-difluoro-N-(((4-(trifluoromethyl)phenyl)amino)carbonyl)benzamide) in acetone; 10,000 rad of gamma irradiation from a ^{137}Cs source while the weevils were anesthetized in N2, followed by a 5 sec dip in a 0.1% solution of diflubenzuron (N-(((4-chlorophenyl)amino)carbonyl)-2, 6-difluorobenzamide) in acetone; and a total dose of 6750 rad administered in 25 fractions of 270 rad each in the pupal and early adult stages. Egg hatch in the plots into which the treated males and untreated males were released in a 120:40 ratio along with the 300 untreated virgin females was significantly lower than in plots into which only untreated weevils were released (<73 vs. 98%). Overall competitiveness of sterile males to untreated males was 23.0% for the fumigation treatment, 16.9% for the acute irradiation treatment, and 12.0% for the pupal fractionation treatment. There was no significant difference in competitiveness between the acute irradiation and fumigation treatment. Because of the safety and simplicity of the acute irradiation plus diflubenzuron treatment, we proposed it for sterilizing boll weevils for the North Carolina-Virginia Boll Weevil Eradication Trial program.

939. ; Nilakhe, S. S.; and McGovern, W. L. 1979. Field competitiveness of sterile male boll weevils. J Ga. Entomol. Soc. 14: 114-120.

Male boll weevils, Anthonomus grandis Boheman, were treated with either an acute dose of gamma irradiation (7.0 krad) plus a dip in a 0.02% acetone solution of diflubenzuron (N-[[(4-chlorophenyl) amino] carbonyl]-2,6-diflubenzuron.

940. Vinson, S. B.; Barfield, C. S.; and Henson, R. D. 1977. Oviposition behavior of Bracon mellitor, a parasitoid of the boll weevil (Anthonomus grandis). II. Associative learning. Physiol. Entomol. 2: 157-164.

The parasitoid, Bracon mellitor, will probe with its ovipositor plant structures containing its host. The identification of methyl parahydroxybenzoate (methyl parasept), an antimicrobial additive to the semi-synthetic diet used for rearing the host, as a releaser of this behavior prompted an investigation of the parasitoid's response to this chemical. Its absence from field hosts suggested the response was learned. Female parasitoids reared in host-infested cotton plant buds from the field or in methyl parasept-free hosts did not respond to methyl parasept alone until exposed to hosts contaminated with it. This is taken to imply associative learning by the females reared from the methyl parasept-free hosts. A few responses to methyl parasept were elicited from inexperienced females reared from methyl parasept-contaminated hosts, but their responsiveness increased after they had been exposed to methyl parasept-contaminated hosts as oviposition stimuli. These results point to the caution that must be exercised in the isolation and identification of kairomones.

941. ; Henson, R. D.; and Barfield, C. S. 1976. Ovipositional behavior of Bracon mellitor Say (Hymenoptera: Braconidae), a parasitoid of boll weevils (Anthonomus grandis Boh.). I. Isolation and identification of a synthetic releaser of ovipositor probing. J. Chem. Ecol. 2: 431-440.

Female Bracon mellitor Say responded to the frass of diet-reared boll weevil larvae by probing with the ovipositor. Similar responses were elicited by the hexane and chloroform-methanol fractions after differential extraction of boll weevil feces. The active component of the chloroform-methanol fraction was identified as methyl p-hydroxybenzoate (methyl parasept). Because the methyl parasept is an artificial component of the diet, the results suggest that the parasitoid response may be associatively learned. The response to methyl parasept decreased with time in the absence of reinforcement. Results demonstrate that certain chemicals may release behavior normally evoked by kairomones, and may interfere with the isolation of natural kairomones.

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942. Wade, L. J., and Rummel, D. R. 1978. Boll weevil immigration into winter habitat and subsequent spring and summer emergence. J. Econ. Entomol. 71: 173-178.

A study conducted from 1974 to 1977 revealed that emergence patterns of overwintered Anthonomus grandis Boheman were related to the time that boll weevils entered winter habitat. The response of marked weevils to pheromone traps during the spring and summer indicates that weevils which enter overwintering sites during the later half of the fall period tend to emerge later the following growing season than those which enter hibernation early. Leaf litter examinations during the period Aug. 1975-Mar. 1977 indicate that the major buildup of overwintering weevils in hibernation sites occurs through Oct. and Nov. The association between the time of boll weevil entry into overwintering habitat and the time of emergence the following growing season is an important factor to consider in conducting late season boll weevil suppression programs. Data developed during this study indicate that field populations present during Oct. and Nov. should be subjected to maximum control pressure since they tend

to emerge the following year near or after cotton begins fruiting and will have maximum impact on the developing crop.

943. Walker, J. K., Jr. 1966. Overwintered boll weevil infestations in trap crop plantings, 1960-66. Tex. Agric. Exp. Stn. Prog. Rep. PR-2433, 4 pp.

Examination of the data shows that, in the 7-year period, there was a great deal of emergence in June, often quite late in June. In 4 of the 7 years important numbers emerged after the first one-third grown squares appeared. If a pre-square application of insecticide had been made, a large number of insects consequently would have been unaffected. Also, it is obvious that one could not aslect a calendar date and predetermine an "automatic" control program for an insecticide application; the date of maximum populations varied from June 8 to June 28. These findings are at considerable variance with the 50 years of hibernation cage emergence data.

944. . 1966. The relationship of the fruiting of the cotton plant and overwintered boll weevils to the F_1 generation. J. Econ. Entomol. 59: 323-326.

Studies at College Station, Texas, in 1960-64 on the populations dynamics of the boll weevil in an isolated plot showed that generation rates of increase varied from 2- to 40-fold. Differences seemed attributable to the magnitude of the overwintered generation. The larger populations of overwintered weevils limited square production, thereby limiting oviposition sites. Consequently, proportionately fewer F_1 resulted than from small overwintered populations. Peak F_1 emergence was associated with the peak blooming period of the cotton in the plot.

945. . 1967. Studies in the fall and winter of oviposition prior to diapause in the boll weevil with observations on reversion from diapause to reproduction. J. Econ. Entomol. 60: 798-802.

Studies of isolated female boll weevils, Anthonomus grandis Boheman, in the fall

and early winter seasons of 1963, 1964, and 1965 showed that oviposition prior to diapause was negligible. However, diapausing females about 30 days old often became reproductive. Observations on the general behavior of the females are given.

946. . 1969. Infestations of overwintered and summer-generation boll weevils near College Station, 1960-68. Tex. Agric. Exp. Stn. Prog. Rep. PR-2701, 9 pp.

Studies of overwintered boll weevils in the trap crop plantings of cotton showed that time of greatest infestations was variable with peak numbers occurring after mid-June more than 50 percent of the time. Results obtained from pheromone traps were similar to data recorded in the trap plots. Results of the 9 years of experimentation show the difficulty of scheduling automatic insecticide programs for overwintered boll weevils that would be highly reliable in affording good control every season. Data on the summer and fall migration of the boll weevil to the trap plantings and pheromone traps showed that major migration does not occur until late August or about the time of F_3 generation. However, in the 1967 season, some movement of the insect was noted throughout the summer prior to the time of the large migrating F_3. Summer and late summer migration occurred at a time when most of the cotton in the test area was being treated with scheduled applications of insecticides.

947. . 1980. The development of short-season cotton production in Texas. Proc. 1980 Beltwide Cotton Prod. Res. Conf., pp. 153-155.

With a sudden abruptness, the development of insecticide resistance in the *Heliothis* complex, in the 1960's, called to examination the entire process of multi-applications of insecticides for the control of cotton insects; in a stroke a strategy that had risen out of the arduous experiences of entomologists after the turn of the century now assumed a devaluation. For the first time we in the State

took focus on a more updated horizon of cotton production. It bore little resemblance to 1900; and we realized that options were open that were never imagined at the turn of the century. Technology, shifts in cotton acreages, and understandings had come a long way -- and from this realization the joint efforts of growers, extension and research personnel have hammered out production strategies that appear to face insect problems in an integrated pest management manner. The paper briefly chronicles some of this redirection in the State.

948. . 1980. Earliness in cotton and escape from the boll weevil. In Biology and Breeding for Resistance to Arthropods and Pathogens in Agricultural Plants. Tex. Agric. Exp. Stn. Misc. Publ. MP-1451, pp. 113-123.

Where boll weevils are delayed in their buildup to injurious numbers until the second generation, rapid-fruiting in cotton can allow substantial lint production. Experiments have established that if the infestation is so delayed, a large part of the crop will be in the boll stage; and the weevil is much less a pest to bolls than to squares. As a boll grows older each day, so decreases the probability it will be damaged by the pest: The more rapid bolls are set and accumulated, the greater the yield possibilities. Certain genotypes and narrow-row planting schemes can hasten the acquisition of bolls earlier in the fruiting sequence. One commercial variety, TAMCOT SP-37, has demonstrated that it suffers less boll damage than several other cottons.

949. , and Bottrell, D. G. 1970. Infestations of boll weevils in isolated plots of cotton in Texas, 1960-69. J. Econ. Entomol. 63: 1646-1650.

Studies of infestation patterns of overwintered and summer-generations of Anthonomus grandis Boheman were carried out in Texas from 1960 to 1969 in isolated plots of cotton. Movement of overwintered insects to the plots was detected from the last week in May until late June. Generally, a period of peak

infestation was noted. Peaks were not related to rainfall or to ground-litter temperatures. During 1967, dispersal of the summer generation began in late June and increased as the summer progressed. The greatest dispersal during 1967, 1968, and 1969 occurred from mid-August until well into September. Dispersal also was monitored during 1968 and 1969 using traps baited with male boll weevils. Findings were similar to data recorded in the plots. Observations of dissected overwintered weevils collected in the plots showed that diapause had been terminated by the time of collection. Mature eggs appeared as the first squares formed. Observations of dissected summer- and fall-generation weevils from plots and traps indicated that both reproductive and diapausing individuals disperse.

950. ; Frisbie, R. E.; and Niles, G. A. 1978. A changing perspective: Heliothis in short-season cottons in Texas. Bull. Entomol. Soc. Am. 24: 385-391.

The foregoing paragraphs describe what is followed in Texas - rapidly fruiting cottons, early-season control, "diapause weevil control", willingness to accept outbreaks of Heliothis before blooming, a restrained approach in reacting to later infestations of Heliothis - but it should be underscored that the success of this strategy for cotton grown outside of the Plains country hinges on early planting. For cotton planted 30-45 days after optimum dates in eastern or southern Texas, there is no greater assurance of production unassailed by Heliothis (or boll weevils) than there was in the time of Mally or Quaintance or Brues. A functioning short-season scheme with its inherent insect escape characteristics means a crop planted early; a substantial delay in planting neutralizes the benefits.

951. ; Gannaway, J. R.; and Niles, G. A. 1976. The age distribution of cotton bolls and damage from different generations of the boll weevil. Tex. Agric. Exp. Stn. Misc. Publ. MP-1254C.

Releases simulating first and second generation boll weevils, Anthonomus grandis, were made on two cotton genotypes, and effects on production were noted. First generation insects caused severe reductions in yields. When weevil release was delayed until the second generation, yields were only moderately decreased. First generation weevils produced their damage by both square and boll attack; second generation insects were a threat to bolls. Bolls of the short-season cotton, DSR 1x6-56, which were 12 days or older were relatively safe from weevil attack.

952. ; Gannaway, J. R.; and Niles, G. A. 1977. Age distribution of cotton bolls and damage from the boll weevil. J. Econ. Entomol. 70: 5-8.

Releases simulating 1st and 2nd generation Anthonomus grandis (Boheman) were made on 2 cotton genotypes, and effects on fruiting, fruit damage, and yields were noted. First generation releases caused severe reductions. The release of twice as many weevils in the 2nd generation moderately reduced yields. First generation produced damage by way of square and boll attack; 2nd generation insects primarily were a threat to bolls. Bolls 12 days old or older at the time of the beginning infestation of 2nd generation weevils of the short season genotype DSR 1x6-56 were relatively safe from weevil injury. Subplots of this cotton averaged 300-500 lb acre in bolls that were 13 days or older on the 2nd day of the 2nd generation period.

953. , and Hanna, R. L. 1966. Effects of the boll weevil and bollworm on cotton quality. J. Econ. Entomol. 59: 265-267.

Cotton-quality tests were conducted on lint and seed samples collected from a series of insecticide experimental treatments. Despite considerable damage to

bolls by the boll weevil, Anthonomus grandis Boheman, and the bollworm, Heliothis zea (Boddie), cotton quality was not affected.

954. ; Hart, E. R.; Gannaway, J. R.; and Niles, G. A. 1979. Boll weevil and thrips resistance in pilose cotton. Southwest. Entomol. 4: 132-140.

Field and cage studies in Texas showed that the "locked square" character of Pilose cotton reduced % of punctured squares from the boll weevil, Anthonomus grandis Boheman, and this translated into greater bloom production. This cotton also expressed resistance to thrips, Frankliniella spp.

955. , and Niles, G. A. 1971. Population dynamics of the boll weevil and modified cotton types, implications for pest management. Tex. Agric. Exp. Stn. Bull. B-1109, 14 pp.

The population dynamics of the boll weevil in cotton was investigated near College Station from 1960 to 1963 and from 1965 to 1968. Findings showed that the time of weevil generations in cotton was predictable. Rates of increase of first generation insects from small numbers of overwintered weevils were as great as thirty-fold. When large populations of the overwintered pests infested cotton, a reduction in reproductive efficiency occurred. Rates of increase of twofold to five-fold were recorded. Economic threshold data showed that overwintered populations must be reduced to about 22 females per acre in order not to experience damage from the first generation. Forty or more overwintered females per acre produced ample first generation weevils to inflict heavy damage. When Lankart Sel. 57 cotton was used, it was apparent that the major threat of boll weevil damage would result from the first generation. That is, if cotton escaped damage from this generation, the crop would be too mature to experience damage from the second generation, regardless of the size of the second generation. Concepts gained from this study dramatize the importance of early maturing cottons in escaping boll weevil damage and in reducing winter carryover of diapausing individuals. Certain

new experimental strains of cotton, when planted in high density culture, seem to escape weevil damage and reduce winter carryover.

956. ; Niles, G. A.; Gannaway, J. R.; Bradshaw, R. D.; and Glodt, R. E. 1976. Narrow row planting of cotton genotypes and boll weevil damage. J. Econ. Entomol. 69: 249-253.

Studies of the relationship of Anthonomus grandis Boheman to short season cottons cultured in different planting arrangements were carried out in Texas for 3 seasons; a single experiment was conducted in each season. Effective blooming periods of ca. 30 days before buildup of 2nd generation boll weevil populations resulted in yields of 600-800 lb lint/acre from certain genotypes. This increased production was associated with the ability of a genotype to retain a high percent of its flowers during the blooming period. Maximum earliness and yields were recorded with genotypes planted 2 drills on 40-in. beds or single drills on 26 2/3-in. beds.

957. Warner, R. E. 1966. Taxonomy of the subspecies of Anthonomus grandis (Coleoptera: Curculionidae). Ann. Entomol. Soc. Am. 59: 1073-1080.

In the years since the thurberia weevil, Anthonomus grandis thurberiae Pierce, was described, attempts to separate it from the boll weevil, A. g. grandis Boheman, by using the characters noted by Pierce have met with indifferent success. In an intensive study of specimens clearly representative of the 2 named subspecies of grandis, 3 characters were found to distinguish thurberiae from grandis, namely, curvature of the setae of the pronotrum, sculpture of the metepisternum, and shape and sculpture of the scutellum. When these characters were used to define the limits of distribution of thurberiae and grandis, not only was the distribution of the 2 weevils revealed, but also some populations were found to differ from typical forms of both. The name Anthonomus grandis grandis is used for the boll weevil of the Southeastern United States; the

thurberia weevil is Anthonomus grandis thurberiae; and the intermediate form, wherein the holotype of grandis falls, is called simply "intermediate." The data from an examination of more than 4000 specimens are grouped according to geographical areas, and the combined frequency data of the 3 characters of Anthonomus grandis spp. within the populations show the percentages falling into thurberiae, intermediate, and grandis.

958. , and Smith, C. E., Jr. 1968. Boll weevil found in pre-Columbian cotton from Mexico. Science 162: 911-912.

A well-preserved, teneral adult female boll weevil, Anthonomus grandis Boheman (broad sense), was discovered in fragments of a cultivated cotton boll found in Guila Nacquitz Cave, Level A, dated about A.D. 900, near Mitla, Oaxaca, Mexico. This find antedates any previously known association of the boll weevil with cultivated cotton by about 900 years and negates the contention that this association began in the 18th century. The specimen is intermediate in form between Anthonomus grandis grandis Boheman and the thurberia weevil, Anthonomus grandis thurberiae Pierce.

959. Warren, L. O. 1978. Introduction. In Boll Weevil: Management Strategies. South. Coop. Ser. Bull. 228, p. 3.

To explore the level of current technology, to provide a basis for developing a more highly coordinated approach for the suppression of the boll weevil, and to suggest management programs of immediate and practical application, researchers at state agricultural experiment stations, all well-known as authorities in their respective fields, have contributed to the development of this bulletin. There is deep appreciation for the necessity of combining the knowledge from all appropriate disciplines and synthesizing this information into practical application to reduce the losses caused by the boll weevil. The state agricultural experiment stations, with their pool of expertise and a long record

of experience dealing with the boll weevil and related problems, will continue to emphasize the development and use of all available technology to suppress the boll weevil.

960. Weaver, J. B. Jr.; All, J. N.; Weaver, D. B.; and Hornyak, E. P. 1979. Influence of various insecticides on yield parameters of two cotton genotypes. J. Econ. Entomol. 72: 119-123.

Yield parameters (insect control, lint yield, lint percentage, and micronaire) of 2 cotton, Gossypium hirsutum L., genotypes ('Coker 310', an adapted cultivar, and an insect nonpreferred strain, OFNRS = okra leaf, frego bract, nectariless, and red stem) varied according to different insecticide spray programs. Insecticides included organophosphates, pyrethroids, organophosphate:pyrethroid combinations, and an experimental molt inhibiting insecticide. Bollworms, Heliothis spp., and the boll weevil, Anthonomus grandis grandis Boheman, were reduced in the OFNRS genotype and yield was significantly higher than Coker 310 during an intense infestation when chemical control was poor. Of 14 insecticide treatments tested, combinations of certain pyrethroids with methyl parathion had greatest efficacy and yield of seed cotton. Fiber properties were influenced by insecticide treatment and date of initial spray application.

961. , and Reddy, M. S. 1977. Boll weevil nonpreference, antibiosis, and hatchability studies utilizing cotton lines with multiple non-preferred characters. J. Econ. Entomol. 70: 283-285.

Percentages of squares (flower buds) with oviposition punctures of Anthonomus grandis Boheman were determined on cotton plants, Gossypium hirsutum L., that carried various combinations of characters nonpreferred by boll weevils or showing antibiosis. Strains were grown with and without the use of insecticides at the Plant Sciences Farm, College Experiment Station, University of Georgia in 1974. Oviposition was reduced by the characters: frego bract, cytoplasmic male-

sterility and red stem. The 3 characters were cumulative in imparting nonpreference and, to some extent, in reducing hatchability. Lint yield of some strains with multiple nonpreferred characters was equal to 'Coker 201' in a yield test grown under adequate insect control and was significantly higher where no insecticides were applied.

962. Weidhaas, D. E. 1968. Field development and evaluation of chemosterilants. In Principles of Insect Chemosterilization, G. C. La Brecque and C. N. Smith (Eds.), pp. 275-314. Appleton-Century-Crofts, New York.

An extensive effort on the laboratory development and evaluation of chemosterilants had led to preliminary field testing of chemosterilants with a variety of insect species and different methods of utilizing these materials. This research is summarized by insect species which have been studied including house flies, screwworm, Mexican fruitfly, mosquitos, cabbage looper, boll weevil, pink bollworm and codling moths.

963. Wendell, L. E., and Bull, D. L. 1970. Systemic activity and metabolism of dimethyl p-(methlythio)phenyl phosphate in cotton. J. Agric. Food Chem. 18: 420-424.

Studies were made of the fate of ^{32}P-labeled dimethyl p-(methylthio)phenyl phosphate (Allied Chemical Co. compound GC-6506) in field-grown cotton after different methods of treatment. GC-6506 was oxidized very rapidly in plants to the sulfoxide form and more slowly to the sulfone. The oxidative derivatives were shown to be more active than GC-6506 as anticholinesterase agents, but were slightly less toxic to adult boll weevils, Anthonomus grandis Boheman, after topical application. GC-6506 applied to the main stems of cotton plants was absorbed readily and translocated to all parts of the plant except the fruit. The compound also was absorbed rapidly after application to the surfaces of the leaves. The biological half-lives of GC-6506 and its oxidative derivatives inside

the plant did not exceed two days, and all toxicants were usually depleted after four weeks. The degradation of toxic compounds involved cleavage of the O-methyl and P-O-phenyl linkages.

964. White, J. R., and Rummel, D. R. 1978. Emergence profile of overwintered boll weevils and entry into cotton. Environ. Entomol. 7: 7-14.

Small plots of cotton and pheromone traps were used to study the emergence profile of overwintered boll weevils, Anthonomus grandis Boheman, and their entry into cotton. Boll weevil movement into cotton was closely related to the phenology of the plant. Very few overwintered weevils entered presquaring cotton but immigration increased with increasing size and number of squares. Results of this study indicate that overwintered weevil colonization is not a result of random entry into cotton followed by pheromone production. Rather, overwintered weevil immigration into cotton appears to be a positive response to squaring cotton, with attraction greatly intensified by pheromone production after weevils feed on squares. Overwintered weevil response to pheromone traps appeared to provide a relatively accurate index of population size and activity. In the study area pheromone traps indicated that the major portion of the overwintered population was active several weeks before weevil colonization occurred in cotton. These data indicated that ca. the last 10% of boll weevils emerging from overwintering habitat contributed the major portion of the population that entered cotton. The relationship between the number of weevils responding to pheromone traps and the number entering the cotton plots indicates that pheromone traps can be used to predict the degree of overwintered boll weevil infestation which will occur in cotton.

965. ; Rummell, D. R.; and Wade, L. J. 1977. A new concept in boll weevil pheromone trap design. Southwest. Entomol. 2: 37-41.

A new type of boll weevil pheromone trap was developed and tested during the

1976 season. The new trap retains several advantages of the widely used Leggett trap, but operates on an entirely different principle and shows promise of being more efficiency in capturing boll weevils. A modified version of the Leggett trap also was tested and proved superior to the standard Leggett design.

966. Whitten, C. J., and Bull, D. L. 1978. In vivo effect of a juvenile hormone analogue on the nonspecific esterases of the boll weevil. Southwest. Entomol. 3: 226-231.

Topical applications of a juvenile hormone analogue (Zoecon 1330-193A, (E,E)-9-(3,3-dimethyloxiranyl)-N,N-diethyl-3, 7-dimethyl-2, 6-nonadienamide) to newly formed pupae of the boll weevil, Anthonomus grandis Boheman, resulted in integumental defects of varying degrees in a proportion of the insects. Quantitative and qualitative comparisons of the nonspecific esterase and crude protein compositions among treated and untreated insects revealed differences between categories of treated insects and between treated and untreated insects. The greater the severity of the disruption of the normal metamorphical processes among the treated insects, the greater was the deviation of biochemical properties from that of the untreated insects.

967. Whitten, M. T., and Foster, G. G. 1975. Genetical methods of pest control. Annu. Rev. Entomol. 20: 461-476.

Current status of the sterile insect release method including the screwworm, coldling moth and boll weevil is discussed.

968. Widemann, H. T.; Slosser, J. E.; and Cross, B. T. 1979. Tree uprooting with a low-energy grubber for shelterbelt thinning. Trans. ASAE 22: 1275-1279.

A small crawler tractor with a hydraulic-activated root-cutting blade uprooted large trees very effectively. In trees with a mean trunk diameter of 26 cm

(10.4 in.) and a range from 10 to 56 cm (4 to 22 in.), the average uprooting time was 3.2 min/tree. At $22.50/h, the low-energy grubber averaged $1.20/tree.

969. Widstrom, N. W. 1979. The role of insects and other plant pests in aflatoxin contamination of corn, cotton, and peanuts - A review. J. Environ. Qual. 8: 5-11.

The relationship of insects to certain fungi and moldy agricultural commodities has received special attention in the last several years since it was determined that some of the fungi produce aflatoxin and other toxic metabolites. These fungi and their toxic by-products have been suggested for use as insecticides, as a source of stable chemosterilants, and as potentially effective biological control agents for various insect species. The principal role of the insect in the toxin contamination of agricultural commodities is believed to be one of predisposing plant tissue to invasion by the fungus. The European corn borer, Ostrinia nubilalis (Hubner), the corn earworm, Heliothis zea (Boddie), and the fall armyworm, Spodoptera frugiperda (J. E. Smith), have been identified as the major insects implicated in Aspergillus flavus infection and subsequent aflatoxin contamination of pre-harvest corn (Zea mays L.). The pink bollworm, Pectinophora gossypiella (Saunders), and, to a lesser extent, the boll weevil, Anthonomus grandis Boheman, appear to be influential in predisposing cotton (Gossypium hirsutum L.) and cotton seed to A. flavus infection. The available literature does not provide conclusive evidence to positively link the pests of peanuts (Arachis hypogaea L.) with aflatoxin contamination of that crop. Therefore, insect control is expected to be less helpful in solving the aflatoxin contamination problem on peanuts than on corn or cotton.

970. Wiygul, G., and Mitlin, N. 1976. Oxygen uptake in male and female boll weevils, Anthonomus grandis Boheman (Coleoptera: Curculionidae), of the ebony strain fed a laboratory diet. Comp. Biochem. Physiol. 54A: 249-251.

1. Oxygen uptake was measured in laboratory diet-fed 1- to 15-day old male and female boll weevils of the ebony strain. 2. O_2 uptake was found to be between 27·24 to 6·45 µl O_2/mg wet wt per hr for males and between 26·37 and 5·64 µl O_2/mg wet wt per hr for females. 3. Peak O_2 uptake for males was recorded when they were 4 and 12 days old. 4. Peak O_2 uptake for females was recorded when they were 6, 10, and 14 days old.

971. , and Mitlin, N. 1977. Oxygen uptake in male and female boll weevils, Anthonomus grandis Boheman (Coleoptera: Curculionidae), of the ebony strain fed cotton squares (buds). Comp. Biochem. Physiol. 56A: 395-397.

1. Oxygen uptake was measured in 1-to 15-day old male and female boll weevils of the ebony strain that were fed cotton squares (buds). 2. O_2 uptake was found to range between 19.51 and 10.64 µl O_2/mg wet wt/hr for males and between 17.6 and 11.1 µl O_2/mg wet wt/hr for females. 3. Peak O_2 uptake for males was recorded when they were 5 and 11-12 days old. 4. Peak O_2 uptake for females was recorded when they were 6 and 12 days old.

972. , and Haynes, J. W. 1974. A locomotor test for the prediction of sterility in boll weevils. Entomol. Exp. Appl. 17: 452-453.

Since disease and malnutrition also have an effect on the vigor of boll weevils, such a test as we have described can be used only when the procedures in the rearing facility are such as to maintain vigor and when tests are made if disease or malnutrition is suspected. These potential problems notwithstanding, the locomotor test was used successfully during the 1973 phase of the PBWEE to determine the degree of sterility of chemosterilant-treated male boll weevils. It was especially valuable when the results of tests made at the beginning of the release program indicated that the boll weevils were not being fed an adequate quantity of chemosterilant to render them sterile. The deficiency was immediately corrected by feeding the weevils the chemosterilant an extra day. It would have

taken ca. 3 weeks to determine that this problem existed by using previously available methods.

973. ; Mitlin, N.; Love, J. N.; and Lusk, G. J. 1970. The absorption and metabolism of glycine-U-^{14}C in the irradiated and normal boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae). Comp. Biochem. Physiol. 33: 475-480.

Three-day-old boll weevils, Anthonomus grandis Boheman, that had been irradiated 2 days previously with 6kR of gamma irradiation were injected with or force-fed glycine-U-^{14}C, sampled at intervals for 24 hr and extracted for free amino acids, lipoprotein, nucleic acids and protein. Aliquots of the extracts were then counted by liquid scintillation procedures. Differences were found in the rate of absorption of the glycine from the alimentary canal of irradiated and normal insects and in the rate of conversion of free glycine to protein. No differences could be detected in the conversion of label to lipoprotein and nucleic acids.

974. ; Mitlin, N.; and Thompson, A. C. 1971. Metabolism of busulfan in the boll weevil (Anthonomus grandis Boheman). Pestic. Biochem. Physiol. 1: 418-423.

One-day-old male boll weevils, Anthonomus grandis Boheman, that had been force-fed ^{3}H, and ^{14}C-labeled busulfan were held for 24 and 72 hr, respecitvely. The resulting metabolites from the feces and extracts of the weevils were analyzed by thin-layer chromatography, gas-liquid chromatography, and mass spectroscropy. At 72 hr post-ingestion, 34.32% of the total radioactivity was recovered from the feces, about 1.09% as busulfan. Most metabolism of busulfan appeared to take place within 24 hr post-ingestion. Organic acids, amino acids, busulfan, 1,4- and 2,3-butanediols, and sulfolane were identified as metabolites. Methanesulfonic acids was determined as a metabolite by using unlabeled busulfan.

975. ; Mitlin, N.; Thompson, A. C.; and Lindig, O. H. 1974. Free amino acid levels in the boll weevil (Coleoptera: Curculionidae): the effect of five different diets. Comp. Biochem. Physiol. 49B: 663-667.

1. The levels of eighteen free amino acids were determined in five groups of 5-day-old male boll weevils. 2. Each of the groups of boll weevils had fed, from emergence, on one of three artificial diets, on cotton bolls or on cotton squares (buds). 3. Square-fed boll weevils were compared statistically with the other groups of weevils. 4. Glutamic acid was elevated in all three groups fed artificial diets. 5. Proline and tyrosine were elevated in two groups fed artificial diets; alanine, glycine, arginine, histidine, and tryptophan were elevated in at least one of these groups. Alanine was decreased in one of the groups fed artificial diets. 6. Valine, glycine, isoleucine, leucone, threonine, phenylalanine, aspartic acid and arginine were elevated in boll-fed boll weevils; methionine was decreased.

976. Wolfenbarger, D. A. 1977. Boll weevil, bollworm, and tobacco budworm, and fruiting structures of the cotton plant: number of plants that must be sampled at different square populations and percentage damaged. J. Econ. Entomol. 70: 791-793.

Plants at different stages of growth in 0.4 ha of cotton were sampled by the grid, X pattern, and area systems to estimate number of squares, percentage squares damaged by the boll weevil, Anthonomus grandis Boheman, and percentage squares, flowers, and bolls damaged by Heliothis spp. No system was clearly superior to the others, but fewer plants had to be sampled by the grid and X systems to achieve comparable results with those from the area system. To estimate damage done by Heliothis spp. and the boll weevil, totals of 100-1000 plants had to be sampled. Only 4-20 plants were needed when sampling for squares, and 25-135 for flowers.

977. , and Davis, J. W. 1976. Termination of cotton plants with chemicals and the effect on populations of boll weevils and tobacco budworms. Proc. 1976 Beltwide Cotton Prod. Res. Conf., pp. 46-48.

Single applications of sprays of commercial formulations of the plant growth regulator chlorflurenol (a mixture of 65-70% methyl 2-chloro-9-hydroxyfluorent-9-carboxylate, 18-25% of its nonchlorinated analog, and 10-12% of its 2,7-dichloroanalog). 2,4-D (dimethyl amine salt of [2,4-dichlorophenoxy] acetic acide), or a combination of the two containing 0 5 lb/acre chlorflurenol and 0.025 lb/acre 2,4-D were made to cotton at different intervals after the first flower to teriminate square initiation and development. Plants were examined to determine the effect on feeding and oviposition by the boll weevil, Anthonomus grandis Boheman, and on yields. Neither compound has a direct effect on the development of boll weevil larvae. An application of the combination made 35 days after the appearance of the first flower increased the percentage of open bolls compared with the untreated check, reduced damaged squares 90% while allowing only a 10% increase in bolls damaged by boll weevil feeding, and increased yields.

978. ; Dilday, R. H.; and Davis, J. W. 1979. Fruiting requirements of short-season cottons to avoid damage by the boll weevil in the Lower Rio Grande Valley. Proc. 1979 Beltwide Cotton Prod. Res. Conf., pp. 88-90.

Square populations and percentage open bolls of 'Stoneville 213' and 'Tamcot SP-37' and of 2 single-plant selections of SP-37 (GH-19-8-75 and GH-11-9-75) that demonstrate side-by-side flowring were compared. Both the single-plant selections had 21 to 60% open bolls when 50% of the hypothetical third generation of boll weevils had emerged. Also, these lines had 60 to 90% open bolls 3-7 days earlier than did SP- . and their yields were equal to those of SP-37 and ST-213.

979. ; Dilday, R. H.; and Hartstack, A. W., Jr. 1979. Boll weevil: relationship of predicted vs. observed peaks of populations to squaring rates of two cotton cultivars. Environ. Entomol. 8: 506-511.

From 1973 to 1975, two varieties of cotton, Stoneville ST-213, a standard cultivar, and Tamcot SP-37, a short-season cultivar, planted at ca. 50,400 plants/ha, in river silt in the Lower Rio Grande Valley of Texas, were sampled for adults of the boll weevil, Anthonomus grandis grandis Boheman, and boll weevil larval damage to squares. The predictions of 2 models for the peak emergence of adults of 4-5 generation of boll weevils was then compared to the actual times of peak emergence of weevils in the field. A good relationship was found between the number of days (0-3 days) when adults of F_2 were actually observed in cotton and when they were predicted based on the time for 98% adult emergence. From computed cumulative squaring, 50% of the squares occurred 4 and 9 days earlier on SP-37 than on ST-213 in 1973 and 1974, respectively, and populations of weevils were greater in SP-37 than in ST-213 during 2 of the 3 test yr. Reliable data were accumulated from the sampling of 0.25% of the plot area measuring 204 m^2.

980. ; Graham, H. M.; Parker, R. D.; and Davis, J. W. 1976. Boll weevil: seasonal patterns of response to traps baited with grandlure in the Lower Rio Grande Valley. Environ. Entomol. 5: 403-408.

From 1972-75, more boll weevils, Anthonomus grandis Boheman, were caught in grandlure traps in the lower Rio Grande Valley from mid-August to mid-September after defoliation, harvest,and stalk and root destruction of the cotton than at any other time of the year. Larger numbers were collected in traps after poor stalk and root destruction in August and early September than after good stalk and root destruction. Good and poor stalk and root destruction is judged by the percentage of cotton acres which has been treated in that manner; 100%

of all cotton acreage with all stalks and roots destroyed is good and 90% or less is judged to be poor. More weevils were usually collected in March, the time of plant emergence, than at any other time of year except for the August-September period. In early August 1973 and 1974, the period of defoliation, 69 and 79% of the females and 20 and 53% of the males, respectively, that were collected, were in intermediate to firm diapause.

981. ; Graham, H. M.; Parker, R. D.; and Davis, J. W. 1976. Seasonal patterns of boll weevil response to traps baited with grandlure in the Lower Rio Grande Valley of Texas. In Detection and Management of the Boll Weevil With Pheromone. Tex. Agric. Exp. Stn. Res. Monogr. 8, pp. 20-25.

More boll weevils were caught from mid-August to mid-September following defoliation, harvest, and plow-up than at any other time of the year at Brownsville and Weslaco in the lower Rio Grande Valley of Texas during 1972-74. In both Brownsville and Weslaco, poor plow-up in August and early in September 1973 resulted in larger populations collected in traps than did good plow-ups in August 1974. Weevil collections made in March, at the time of plant emergence, were generally greater than at any other time except for the August-September period. In late-July or early-August of both years, 54 to 79 percent of the females and 8 to 53 percent of the males were in intermediate to firm diapause, which coincided with defoliation.

982. ; Guerra, A. A.; and Garcia, R. D. 1977. Diflubenzuron[sic]: effect on the tobacco budworm and the boll weevil. J. Econ. Entomol. 70: 126-128.

The LC_{50} of diflubenzuron, (N-[[4-chlorophenyl) amino]carbonyl]-2,6-difluorobenzamide), for neonate larvae of the tobacco budworm, Heliothis virescens (F.), was 1.3 X 10^{-3}% wt/vol when it was incorporated into the diet. The LC_{50} for pupae was 1.3 X 10^{-4}% wt/vol in the larval diet. With diets containing 1 X 10^{-2}%,

86-100% of the larvae died, and no adults emerged. In a field-cage test following spray applications of diflubenzuron (0.25 lb/acre in 10% cottonseed oil) to cotton plants, 89% of the tobacco budworm larvae were in the 1st or 2nd instar at a time when the check only had 52% in those stages, indication of a retardation of the larval cycle. Also, emergence of F_1 boll weevils, Anthonomus grandis Boheman, from 1/3-grown and full-grown squares was reduced 66 and 27%, respectively.

983. , and Harding, J. A. 1977. Activity of O-ethyl S-propyl organophosphorus compounds against tobacco budworms and boll weevils. J. Econ. Entomol. 70: 92-94.

In the laboratory, sprays of organophosphorus compounds with the O-ethyl S-propyl moieties were 5-100X more active against a susceptible strain of the tobacco budworm, Heliothis virescens (F.), and all except ER-9700, 9362, 9306, and NTN-9306 were 2-3X more active against the boll weevil, Anthonomus grandis Boheman, than certain alkyl or aryl 0,0-dialkyl organophosphorus compounds. LD_{50}'s for topical applications of Bay NTN-9306, (O-ethyl O-[4-methylthio) phenyl] S-propyl phosphorodithioate) to a susceptible and a field-collected strain of the tobacco budworm differed ca. 8X (0.024 and 0.19 mg/g after 48 h, respectively); this might indicate a potential for resistance to this new class of organophosphorus compounds. In the field, NTN-9306, Rohm & Haas RH-218 (0-ethyl S-propyl 0-(2,4,6-trichlorophenyl) phosphorothioate), and Ciba Geigy CGA-15324 (0-(4-bromo-2-chlorophenyl) 0-ethyl S-propyl phosphorothioate), each applied at a rate of 1 lb/acre, reduced damage to bolls by Heliothis spp. (predominately the tobacco budworms) 81-85% compared with bolls in untreated plots.

984. ; Harding, J. A.; and Davis, J. W. 1977. Isomers of (3-phenoxyphenyl)methyl (±)-cis, trans-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate against boll weevils and tobacco budworm. J. Econ. Entomol. 70: 226-228.

A laboratory strain of the tobacco budworm, Heliothis virescens (F.), was generally more susceptible to topical application of the cis-, and trans-geometrical isomers of (3-phenoxyphenyl)methyl of (2,2-dichloroethenyl)-2.2-dimethylcyclopropanecarboxylate than field-collected strains. The cis-isomer was more active than the trans-isomer. Low levels of the trans-isomer mixed with the cis-isomer appeared antagonistic to the activity of the cis-isomer against the laboratory strain, but high levels (60 and 75%) appeared synergistic against the laboratory strain. The boll weevil, Anthonomus grandis Boheman, was equally sensitive to both isomers and to the various mixtures of the isomers tested. In field trials, FMC-33297 (60 trans:40 cis) applied at the rates of 0.1-0.2 lb/acre was effective against the boll weevil, tobacco budworm, bandedwing whitefly, Trialeurodes abutilonea (Haldeman), and cotton fleahopper, Pseudatomoscelis seriatus (Reuter), and also against the predator complex.

985. ; McGarr, R. L.; Longoria, R. R.; and Nosky, J. B. 1970. Toxicity of EPN, Accothion, and certain chlorinated hydrocarbons to certain cotton insects. J. Econ. Entomol. 63: 1568-1573.

In tests of candidate insecticides against some cotton insects, ultra low volume (ULV-64 oz/acre or less) sprays of EPN (O-ethyl O-p-nitrophenyl phenylphosphonothioate) were more effective than conventional sprays in field tests against boll weevils, Anthonomus grandis Boheman; tobacco budworms, Heliothis virescens (F.); bollworms, H. zea (Boddie); and pink bollworms, Pectinophora gossypiella (Saunders). ULV sprays of Accothion® (O, O-dimethyl O-4-nitro-m-tolyl phosphorothioate) were effective against the pink bollworm but not against the tobacco budworm and bollworm, and the percentages of loss from the cotton leaf after application as a conventional spray were about the same (88-79%) 4 days after application, whether the pesticide was applied at rates of 1.12 or 17.6 kg/hectare. Isobenzan and isodrin, applied as conventional sprays, were the most toxic of the cyclodiene

insecticides tested against larvae of tobacco budworm. Endrin applied as a conventional spray was toxic to bollworms but not to tobacco budworms; when it was applied as ULV and conventional sprays, 83 and 89%, respectively, were lost from cotton foliage after 4 days. Lindane was the most toxic of 4 benzene hexachloride isomers applied as conventional sprays against larvae of the tobacco budworm. General Chemical GC-9287 (1, 1a, 3, 3a, 4, 5, 5a, 5b, 6-decachlorooctahydro-2-methyl-1, 3, 4-metheno-1H-cyclobuta [cd] pentalen-2-ol) applied as a conventional spray at a rate of 0.56 kg/ha gave 100% kill of larvae of tobacco budworms.

986. , and Redfern, R. E. 1968. Toxicity of five carbamate insecticides to the two-spotted spider mite and larvae of the southern armyworm and the tobacco budworm. J. Econ. Entomol. 61: 580-581.

Of the 5 carbamates duPont 1179 caused the greatest mortality to tobacco budworm larvae in laboratory and field cages and to the southern armyworm in the laboratory. DuPont 1642 was 2nd in effectiveness to both lipidopteran species but more effective than the other materials against boll weevils. DuPont 16424 followed by duPont 1519 was most toxic to the two-spotted spider mites and duPont 1642 was most toxic as a systemic insecticide.

987. Wollenberg, R. H., and Peries, R. 1979. Efficient synthesis of insect sex pheromones emitted by the boll weevil and the red bollworm moth. Tetrahedron Let. 4: 297-300.

Two pests responsible for major destruction of cotton crop are the boll weevil (Anthonomus grandis Boheman) and the red bollworm moth (Diparopsis castanea Hampson). This letter describes facile syntheses of two of the four terpenoid compounds emitted by male boll weevils (stereo-isomers corresponding to 1) and also a potent sex pheromone produced by the virgin female red bollworm moth (2). The routes described use in key steps our recently developed nucleophilic acetaldehyde equivalent, (Z)-2-ethoxyvinyllithium (3).

988. Wright, J. E.; Haynes, J. W.; and Jurd, L. 1978. Cotton, laboratory determination of reproductive inhibitors with the boll weevil. Insecticide and Acaricide Testing 4: 219.

Laboratory reared adults (25 newly emerged, mixed sexes) were immersed in acetone solutions of the candidate chemicals for 5 sec, air dried, and held at 27°C and 60% RH, fresh field squares (cotton buds) were then provided daily (1 square/5 weevils) for feeding and oviposition. Also, the candidate chemicals were placed in the adult diet (0.5%), and newly emerged adults were allowed to feed for 3 days. Eggs from both treatments were collected; one-half the eggs were held for hatch, and one-half the eggs were placed on larval diets for determination of adult emergence. High adult mortality was obtained with chemicals JURD-2693 and JURD 2581 when incorporated within the diet. Chemical JURD 2335 in the diet also gave a reduced adult emergence. None of the compounds were active when tested by dipping in acetone solution.

989. ; Haynes, J. W.; McCoy, J. R.; and Dawson, J. R. 1979. Boll weevil: mating ability, sterility, and survival of irradiated and fumigated adults of different ages. Southwest. Entomol. 4: 53-58.

The percentage of male boll weevils, Anthonomus grandis grandis Boheman, that mated successfully (transferred spermatozoa to virgin females) differed when males were newly emerged or aged (ca. 6 days old) at time of treatment with either irradiation and diflubenzuron or fumigation and penfluron. More males were available to mate after the irradiation treatment because of the significantly higher mortality ($P < 0.05$) among fumigated males at day 7 posttreatment. Both treatments suppressed better than 99% of the F_1 population.

990. ; McCoy, J. R.; Dawson, J. R.; Roberson, J.; and Sikorowski, P. P. 1980. Boll weevil sterility: effects of different combinations of diflubenzuron, antibiotics, fumigation, and irradiation. Southwest. Entomol. 5: 84-89.

Studies were made of sterility, mortality, microbial contamination, and mating behavior of Anthonomus grandis Boheman after different kinds of treatments. Diflubenzuron and antibiotics were administered in the adult diet, and the weevils were further treated by irradiation (10 Krad in a nitrogen atmosphere) or by fumigation with bisazir (P,P, bis (1-aziridinyl)-N-methylphosphinothioic amide). When adults were fed diflubenzuron for 5 days after emergence, followed by irradiation or fumigation on the 6th day, a high level of sterility (99%) was induced. Diflubenzuron treatment apparently reduced sperm transfer and increased mortality, and antibiotics reduced pheromone production.

991. ; Moore, R.; McCoy, J.; Wiygul, G.; and Haynes, J. 1980. Comparison of 3 sterilization procedures on the quality of the male boll weevil, Anthonomus grandis grandis. J. Econ. Entomol. 73: 493-496.

Irradiation (10 krads in a N atmosphere) plus dipping in 0.1% diflubenzuron in acetone of 6 day old A. grandis grandis Boheman was selected over fumigation plus dipping of adults and fractionated irradiation of pupae as the method of choice for sterilization for production of quality weevils. The results for this method were: sterility 98.5% and mortality 34.5% at 7 days post-treatment; mating with sperm transfer 78.5% and 59.6% of normal at 3 and 7 days post-treatment, respectively; and pheromone production of 0.4 mu.g/adult per day. Fumigation plus penfluron produced comparable sterile males, but irradiation was more convenient and safer.

Y

992. Yamamoto, I.; Ohsawa, K.; and Plapp, F. W., Jr. 1977. Effect of the inclusion compounds of pyrethroids and methyl parathion on certain cotton insects. J. Pesti. Sci. 2: 41-49.

Methyl parathion is included in beta-cyclodextrin in 1:2 or 1:1 molar ratio. These and the inclusion compounds of four pyrethroids including bioallethrin,

tetramethrin, resmethrin, and pyrethrins were examined for their insecticidal activity to certain cotton insects under laboratory conditions. Included methyl parathion (1:2 ratio) was as toxic as free one to Anthonomus grandis, while the persistency was remarkably improved, almost all remaining after 10 days on cotton leaves under green house conditions. Inclusion did not much reduce the toxicity of methyl parathion to a parasitoid, Campoletis sonorensis, but the possible reduction in use by inclusion may reduce its side effect to natural enemy of cotton pest insects. Pyrethroids were far less toxic to the parasitoid than methyl parathion and the inclusion further improve the safety characteristic. However, higher doses seemed required for included as compared to free pyrethroids to kill Anthonomus grandis. To Heliothis virescens the included methyl parathion was toxic, but pyrethroids were toxic only by contact, and the insect which fed the included pyrethroids seemed not to be affected.

993. Young, D. F., Jr. 1969. Operation of area-wide diapause programs and results in Mississippi. Proc. 1969 Beltwide Cotton Prod. Res. Conf., pp. 7-9.

A reproduction-diapause program was conducted in 1967 in Mississippi in Sharkey County (south Delta) and in Monroe County (eastern Hill area). The Sharkey County demonstration contained 4,000 acres of cotton belonging to 23 farmers. The Monroe County area contained 4,000 acres belonging to 79 farmers. Farmers in both areas were asked to add an insecticide to the defoliant and to destroy stalks as early as possible. They were advised to use methyl parathion emulsifiable concentrate at 0.5 lb. per acre, Guthion ultra low volume at 0.25 lb. per acre or malathion ultra low volume at 1.25 lb. per acre. Farmers were asked to make additional applications at 10 to 14-day intervals following defoliation. In Sharkey County, no boll weevils were found in the treated area when 12 woods trash samples were taken the following spring. It was not necessary to treat a high percentage of the cotton in the control area for boll

weevils until the first of August and insecticide costs were reduced 30 to 50 percent. In Monroe County, extensive spring woods trash collections indicated that boll weevils surviving the program and the winter weather were small in number. Long-range movement of weevils into the treated area was negligible after June 12. After one insecticide application in early June, growers did not need to apply insecticides again for boll weevil control until mid-August. In 1968, the program was expanded to 51.200 acres of cotton in six counties. Most farmers followed program recommendations, however many did not treat throughout September because cotton matured earlier. The highly effective program the preceding year made it hard to convince some former participants that a need still existed for the program. The 1968 program was successful.

994. . 1976. Activities of the Mississippi Cooperative Extension Service in the Pilot Boll Weevil Eradication Experiment, 1971-73. In Boll Weevil Suppression, Management, and Elimination Technology. Proceedings of a Conference, February 13-15, 1974, Memphis, Tennessee. U.S. Agric. Res. Serv. [Rep.] ARS-S-71, pp. 70-72.

On July 1, 1971, H. C. Mitchell was hired and placed in the area as Extension entomologist to carry out the MCES's activities along with the county agents. Mitchell served as liaison between the various agricultural agencies involved in the program, and in many cases served as a troubleshooter when we found a farmer who was unwilling to carry out certain parts of the program. Mitchell was one of the real keys to the success of the eradication program. Several methods were used to inform cotton producers of the experiment and the ways in which they would benefit from it. Countywide producer meetings, community meetings, individual contacts, radio, television, and newspapers were used to spread information concerning the experiment. Weekly weevil-eradication newsletters prepared by the Extension Service entomologists and mailed by the county agents helped to keep cotton producers informed of current developments. Boll

weevil infestation counts were obtained through the operations office each week and mailed to producers via the county agents. This was extremely helpful to farmers within the area since they were able to use the scouts' reports in determining when to apply insecticides for control. Overall, 64 different newsletters were prepared and mailed to the farmers, amounting to 97,000 individual letters.

995. Young, J. H.; Pinkston, K.; and Price, R. G. 1977. Sequential sampling of the boll weevil in Oklahoma. Okla. Coop. Ext. Serv. [Rep.] CR-7172, 2 pp.

Sequential sampling is probably the quickest most accurate system of making "treat-nontreat" decisions in insect scouting. This system usually reduces sampling time by 50% over other methods. It has been used on a wide variety of insects.

Z

996. Zeck, W.; DeMarshall, A.; and Wybou, A. 1975. Experiments with Bay NTN-9306, in control of Heliothis in cotton in U.S.A. Folia Entomol. Mex. 33: 15-16.

Bay NTN-9306 gave excellent control of Heliothis zea and H. virescens including those resistant to organophosphorus compounds and good control of Alabama argillacea, Spodoptera furgiperda and Lygus spp. In the control plots for Heliothis spp. it gave good control of aphids, spider mites, whiteflies and moderate infestations of Anthonomus grandis.

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